Radiosonde

Replacement System (RRS)

Software Requirements

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1. Introduction

1.1 Scope and Purpose

This document defines the Radiosonde Replacement System (RRS) software requirements and provides and overview of the software development effort. The intent of this document is to consolidate the information necessary for a system specification which will facilitate the functional design of an integrated software system and provide the basis for identifying computer hardware requirements. Two primary objectives of this document are:

- completely and unambiguously define the RRS operational software requirements, including system interfaces.
- serve as a means of communications among all parties working on the RRS.

This document restricts itself to the operational requirements of the RRS. Test plans, implementation plans, statements of work, and the alike are not detailed in this document. The requirements stated in this document are considered to be the minimum set and may be surpassed. Each section in this document describes in detail the operational requirements to be fulfilled before an operational version of the RRS can be implemented in the field.

1.2 Background

The National Weather Service (NWS) operates a network of upper air weather observing stations in the contiguous United States, Alaska, Hawaii, the Pacific Islands, and the Caribbean. At each station, a balloon borne instrument called a radiosonde is sent aloft twice daily to measure atmospheric profiles of the temperature, pressure, moisture, and winds. These radiosonde observations form the backbone of weather forecasts and upper air analyses. Forecasts from these data are used in domestic and international aviation, and in the preparation of national and local weather forecasts and warnings.

The Microcomputer-based Automatic Radio Theodolite (Micro-ART) sounding system, which is currently in operation at upper air sites, provides the functionality for running the upper air observations. This obsolete system, while functional, is aged and does not take advantage of the current technology so the NWS embarked upon a plan to build the RRS to replace Micro-ART. Part of the development of the RRS included the creation of an experimental prototype sounding system to replace Micro-ART. The National Center for Atmospheric Research (NCAR) was contracted to build the NEXt Upper-Air Sounding System (NEXUS) experimental prototype upper air observing system as a step to replacing the current sounding system. The NEXUS system provided a wealth of information about what is and what is not necessary in the replacement system.

The RRS will be the next generation sounding system developed by the NWS. The RRS is an evolution of the previous sounding systems and will encompass the best qualities of both Micro-ART developed by the NWS, and NEXUS developed by the NWS and NCAR. The RRS will utilize state-of-the-art hardware and software, providing soundings with more three-dimensional resolution and accuracy.

1.3 RRS Description

1.3.1 Hardware Environment

The RRS is a combination of firmware, hardware and software. The hardware for the RRS consists of a Pentium Class IBM PC or compatible to run the sounding application; a MET Decoder[1] to provide Pressure and/or Altitude, Temperature, and hUmidity (PTU) values; either a MET Decoder augmentation or the existing RDF telemetry subsystem to provide radiosonde tracking data; a BILS for providing remote release of balloons; and surface observation instruments for providing the workstation software with the surface observation readings during pre-flight.

1.3.2 Software Environment

The software for the RRS will be a self-contained "autonomous" application running on the PC. This software will be coded in a high level language such as C or C++ and contain a user interface based on the Microsoft Windows model. Additionally, the data cataloging, storage system, and inventory control mechanisms will be provided for by an INFORMIX based Structured Query Language (SQL) relational database.

1.4 Software Design Overview

The RRS software will be developed on the concept of pre-processor software (MET Decoder-based) and main processor software (PC-based). The pre-processor software consists of all the operational modules up to, and including, the data collection and conversion into meteorological values, e.g., pressure in hPa. That is, the meteorological data set of variables is the dividing line between the pre-processor and the main processor. The pre-processing of the information will be performed by the MET Decoder, and will allow the radiosonde vendor to modify portions of the pre-processor software and still produce the required data set needed by the RRS software. Any modifications to the pre-processor software will be developed by the Decoder manufacturer. The main processor software will consist of all modules necessary to process the data set generated by the pre-processor into the coded message. Changes to the main processor code will be made by the NWS.

1.5 Implementation Schedule

The development of the RRS will be partitioned into several software builds. These builds will henceforth be known as: Build I or Workstation-ART (WsART); and the Subsequent Builds.

This main focus of this document is on the requirements for the first build of the RRS (WsART). Requirements for the Subsequent Builds of the RRS are specified in Section 12.

1.5.1 Build I (WsART)

The WsART implementation of the RRS will be a standalone fully functional version of the sounding system. WsART will use several pieces of hardware, some new, including a MET Decoder to acquire PTU data from the radiosonde during a flight and a Pentium Class IBM PC or compatible to implement the existing Micro-ART technology. The WsART will continue to use the existing RDF tracking equipment for determining winds.

It is important to note that while the WsART is a part of the RRS development cycle, it will be

1. Refer to the Glossary (Section 13.) for a complete description of the MET Decoder.

developed to be fielded independently of the requirements defined in the subsequent builds. The goals of the WsART build are:

- To realize early implementation of the RRS in the field.
- To replace the aging computer hardware in place at upper-air sites.
- To provide better data resolution.
- To provide more accurate data.
- To provide data to all users in near real time.

Figure 1-1 contains a block diagram of the WsART system.

1.5.2 Subsequent Builds

- The subsequent builds of the RRS will consist of a series of enhancements and additions made to the WsART system. Planned enhancements for the subsequent builds will include:
- Integration with Advanced Weather Interactive Processing System (AWIPS).
- Integration of the Balloon Inflation Launch Shelter (BILS)
- Integration of the automated surface observation equipment.
- Usage of the Global Positioning System (GPS) and GPS radiosondes for determination of winds aloft and radiosonde location.

Figure 1-1: WsART System

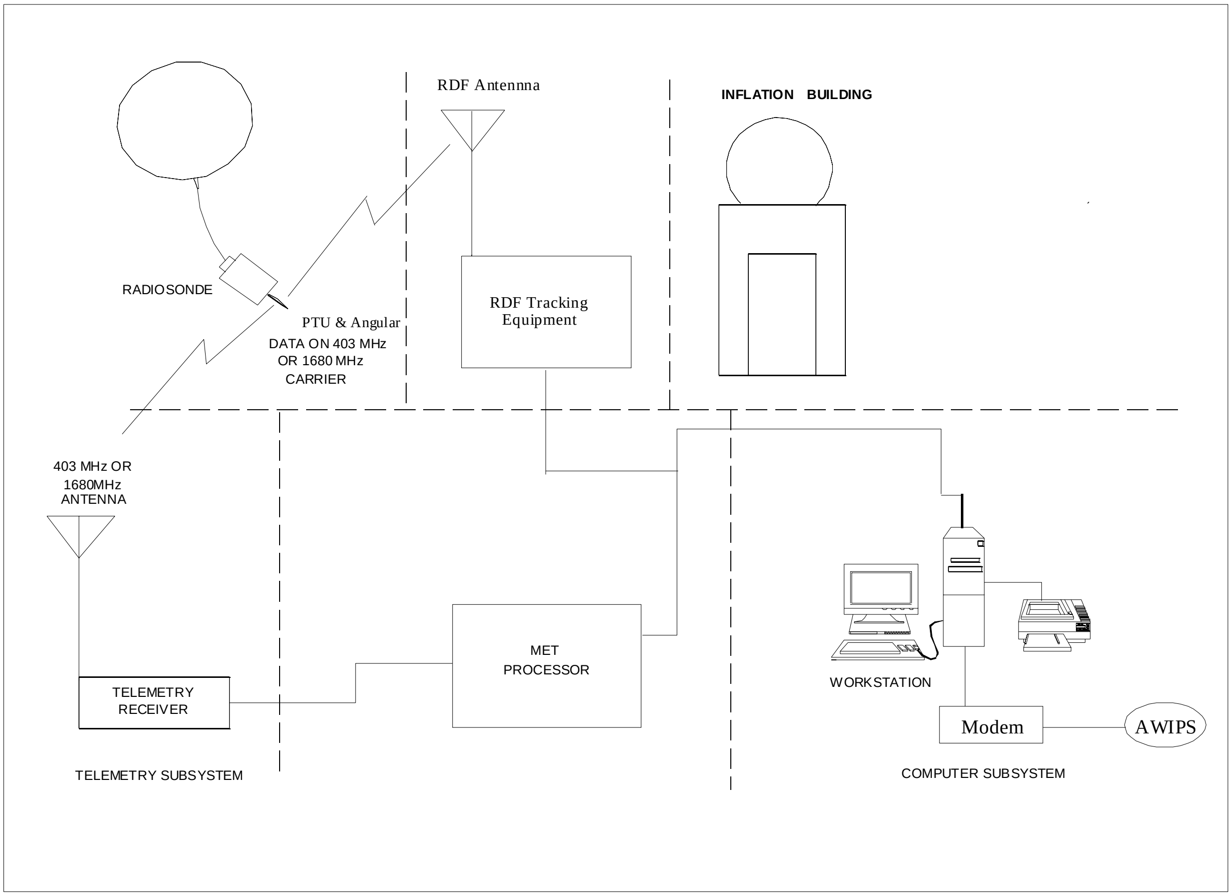


Table 1-1 conatins a list of the major software requirements satisfied in WsART and the Subsequent Builds.

Table 1-1: Software requirements satisfied by build

Software Requirements	Build I (WsART)	Subsequent Builds
RDF Tracking	X	
Interface with BILS		X
PTU data from Decoder	X	X
Automated generation of Upper-air reports	X	X
New Data Product to NCDC & NCEP	X	X

Create Distributed Data Set (DDS)	X	X
Create Processed Data Set (PDS)	X	X
Transmit RADAT message	X	X
Data Transmission to AWIPS	X	X
Transmit WMO Coded Message	X	X
Interface with Surface Obs Equipment		X
Integration with AWIPS		X
Wind data from GPS augmentation to MET Decoders		X

It is critical to note that the development of the different RRS software builds is an evolutionary process and does not represent discrete or independent efforts. The WsART build represents the software infrastructure on which all future builds of the RRS will be based.

1.6 Related Documents

Since the RRS is the next step in the evolution of sounding systems developed for the NWS, all documentation concerning the previous sounding systems are relevant. The following documents are related to the development of the RRS:

Micro-Art Observation and Rework Programs Technical Documentation
Micro-Art System Requirements
Micro-Art Software Documentation Volumes I & II - (no addendums)
Manual on Codes WMO-No. 306
NEXUS Critical Design Review Documentation
NEXUS Interface Design Document
NEXUS Software Design Document
FMH 3 Rawinsonde and Pibal Observations
Signal Processing System Interface Specification (NWS-J070-SP2100)
General Specification for Balloon Inflation and Launch Shelter (NWS-J075-SP0001)
A Guide to WMO Code Form FM 94 BUFR (FCM-I6-1995)
Data Users Requirements Survey, April 1996

2. System Requirements

This section describes the general requirements for WsART. This includes requirements for the Met Decoder interfaced to the PC, other hardware, and the software modules.

2.1 Subsystem Requirements

2.1.1 MET Decoder Requirements

The MET Decoder is responsible for performing data acquisition and front-end processing for WsART. The decoder applies vendor specific transfer equations to the radiosonde telemetry data and provides thermodynamic data to the PC. The PC based software performs any additional processing, storage, and dissemination of the data supplied by the decoder.

The decoder performs the following functions:

- Decode the radiosonde telemetry signal.
- Determine values of pressure, temperature, relative humidity, and optionally, other parameters measured by the radiosonde during its ascent.

The decoder converts measurements transmitted in the radiosonde telemetry to standard units which are usable directly by the workstation software. The reason for performing the conversion in the decoder rather than the workstation is to allow the workstation software to interoperate with radiosondes which employ different techniques for parameter measurement and telemetry.

The WsART PC and the MET Decoder will communicate over an RS232 serial asynchronous communication link (based on EIA-232-D). The communication link will initially be a short, directly-wired, null-modem connection (future links may also be modem-to-modem).

2.2 Client/Server Requirements for WsART

No Client/Server requirements are being placed on WsART. However it is important to note that Client/Server interaction with the workstation will be an important feature in the subsequent builds of the RRS. WsART will be designed such that the Client/Server requirements for the subsequent builds will not require major software changes to integrate. In other words while not providing a client/server interface, WsART will provide a frame work for integrating a client/server interface in future releases.

2.3 Database Requirements for WsART

The previous sounding systems, Micro-ART and NEXUS, used a series of disk-based data files to store information relevant to the upper-air site and soundings. WsART will be required to retain this information as well however, the method in which it will manage the information will be different.

2.3.1 WsART Database

WsART will use an INFORMIX based relational (SQL) database to maintain all system tables. Within this local data base maintained at each site, WsART will store station information, inventory data, and system configuration details, as well as archive and observation data.

Storing inventory data at each site will relieve the observer of the burden of generating the administrative upper air reports. By providing inventory control mechanisms through the local database, the responsibility of generating the administrative reports will be shifted to the PC software.

WsART will be required to provide updates from the upper-air site local database to NWS Headquarters for maintaining a centralized database.

2.3.1.1 Local Database

WsART will not be storing its information in data files but rather, will be maintaining the data in a series of tables making up the upper air database. Storing the flight information in the same database as the inventory information will provide an easy way to generate automated reports and provide one centralized location for managing the upper-air site inventory.

2.3.1.1.1 Station Data Table

The station data table will contain information specific to the upper air site. This information will change infrequently. The station data table will contain the following information:

- Station Name
- Station Latitude
- Station Longitude
- Station Elevation
- Barometer Elevation
- Radiosonde Type
- WMO #
- Station ID
- WBAN Number
- RRS Software Version Number
- Base Pressure
- Release Point Pressure correction
- Release Point Latitude
- Release Point Longitude
- Release Point Elevation
- Ground Equipment
  Radiosonde Receiver Type
  Radiosonde Tracking Method
- Surface Observation Equipment Type
- Surface Observation Equipment Location from Release Point
- Balloon Shelter Type
- Host Computer Phone Numbers
- Limiting Angles Tables

Some of the site specific values such as WBAN Number, station latitude, and longitude are maintained at headquarters. For this reason, a new station data table will be distributed with each version of the WsART software. WsART will display a warning box telling the observer to notify headquarters if any of the station parameters stored at headquarters are modified by the field site.

2.3.1.1.2 Previous Flight Table

The previous flight table will reference data from the last flight processed and will be used to perform comparisons with the current flight data. This table will reference the data from the flight 12 hours ago. If no flight exists from 12 hours ago, the flight from 24 hours ago will be used instead and the observer will be alerted to the change in time. The workstation software will check the surface data entered by the operator prior to balloon launch. If these data appear unreasonable compared with the previous flight data, the workstation software will display a warning message for the observer to review. Additionally, during levels generation, WsART will check the previous flight's levels against the current levels. Any unreasonable changes will cause WsART to generate warning messages for the observer to review.

WsART will retain a configurable amount of previous flights in the local database. The default amount of previous flight data retained in the local database will be 30 days.

2.3.1.1.3 Radiosonde Calibration Table

The calibration table will contain calibration information for a particular radiosonde. The calibration data tables will generally be loaded in when new radiosonde inventory is entered into the database. However, some radiosondes may automatically transmit the calibration data as part of the data stream. In this case, the data would be placed in the table during pre-release. The data contained in this table consists of pressure calibration tables, baselined sensor, and electronic component data used to calibrate a radiosonde.

2.3.1.1.4 Coded Message Table

The code message table will contain the WMO coded message generated by WsART. Entries in this table will remain in the database after the flight and sounding software have been terminated. The data in this table can be recalled, edited, and retransmitted.

2.3.1.1.5 Preflight Data Table

The Preflight Data Table will contain information relating to the observation such as administrative data, flight equipment information, and surface observation data. This table will contain the following information:

Administrative Data:

- Time and Date of the Observation
- Observer Initials
- Ascension Number
- Release Number
- Special Observation (Y/N)
- Termination Level
- Processing Winds (Y/N)
- Process Ranging Data (Y/N)
- Observer (NWS or contract)

Flight Equipment Data:

- Radiosonde Serial Number
- Radiosonde ID
- Radiosonde Type
- Balloon Size
- Balloon Manufacturer
- Balloon Date of Manufacture
- Balloon Gas
- Train Regulator (Y/N)
- Lighting Unit (Y/N)

Surface Observation Data:

- Surface Temperature (Dry-Bulb)
- *Surface Temperature (Wet-Bulb)
- *Surface Temperature (Dew point)
- Surface Pressure
- Temperature 12 or 24 Hours ago (if Surface pressure < 1000 hPa)
- *Surface Relative Humidity
- Surface Wind Speed and Direction
- Clouds and Weather
- Corrected Pressure

* - Note that only one of these three values will be entered. The observer will have the choice of which value. The other two values can be determined from the selected value and other surface observation values.

2.3.1.1.6 Log Table

The Log Table will contain all data not captured in the other flight files or database tables. Included in the log table will be information such as event markers selected during an observation. All event markers stored in this table represent events selected by the observer.

2.3.1.1.7 Meteorological Data Table

The Meteorological Data Table stored in the database will contain all met data acquired during an observation and all processed data generated by WsART. The following information will be stored in the Meteorological Data Table:

- Time (**U**niversal **T**ime **C**oordinated- UTC)
- Decoder Temperature
- Decoder Temperature Quality Indicator (Optional)
- Decoder Relative Humidity
- Decoder Relative Humidity Quality Indicator (Optional)
- Decoder Pressure
- Decoder Pressure Quality Indicator (Optional)
- Processed Temperature Quality Indicator
- Processed Relative Humidity Quality Indicator

- Processed Pressure Quality Indicator
- Processed Temperature
- Processed Relative Humidity
- Processed Pressure

2.3.1.1.8 Position Data Table

The Position Data Table will contain antenna position information related to the radiosonde during its ascent/descent. In WsART, the RDF system will be used to track the radiosonde. The Position Data Table will contain the following information:

- RDF Time Stamp (0-999)
- Elevation and Azimuth Angles
- Limiting Angle Indicator

2.3.1.1.9 Flight Status Table

The Flight Status Table will contain messages about the flight while it was in progress. These messages indicate events/anomalies recognized in a flight, warnings, and information messages about the observation.

2.3.1.1.10 Flight Summary Table

The Flight Summary Table will contain summary information related to the observation such as:

- Amounts of missing, rejected, and poor quality PTU and winds data.
- Termination height for PTU
- Maximum wind
- Winds termination
- Ascension rate
- Lowest temperature and corresponding pressure

2.3.1.1.11 Levels Table

The Levels Table will contain the meteorological data levels selected and the reason for the level selection. The data in this table will be used as a basis for generating the coded message. The following information will be stored in the levels data table:

- Standard Isobaric Surfaces
- Tropopause Level(s)
- Maximum Wind Levels
- Vertical Wind Shears
- Significant Temperature & Relative Humidity Levels
- Significant Wind Levels

2.3.1.1.12 Winds Table

The Winds Table will contain the wind values for the observation. In WsART, the workstation software will be required to compute the wind values based on the tracking data supplied by the RDF. The table will include the following information:

- Time stamp

- U wind component
- V wind component
- Quality U wind component
- Quality V wind component
- Height
- Latitude
- Longitude
- Wind speed
- Wind direction

2.3.1.1.13 Flight Summary Table

The Flight Summary Table will contain a series of parameters calculated or measured during the observation. These parameters are not all computed at the same time.

These values are essential in creating the coded message. The values stored in this table are:

- RADAT Message
- Height and Time for 1000 hPa level
- Height and Time for 925 hPa level
- Height and Time for 850 hPa level
- Stability Index
- Average Ascension rates
  Surface to 400 hPa
  400 hPa to termination
  Surface to 100 hPa
  100 hPa to termination
  Entire Flight
- Tropopause (Time and Height)
  First
  Second
  Third
- Mean winds
- Maximum winds and Time, Height (Primary and Secondary)
- Wind shears
- Minimum and Maximum Pressure, Time and Height
- Minimum and Maximum Temperature, Time and Height
- Minimum and Maximum Humidity, Time and Height
- Termination Reason
- Termination Altitude
- Termination Pressure
- Termination Time or Flight Duration

2.3.1.1.14 Store Table

A Store Table template will be created for each observation. The values for the fields in the store table are available in other tables in the database. For this reason, the store table will not duplicate these values but will contain pointers to the tables that contain the values of interest. The store table will reference all information collected and computed during a flight and that may be used to "rework" an observation after the flight has completed. The store table will contain pointers in the database to the following information:

- Station Data
- Limiting Angles
- Administrative Data
- Flight Equipment information
- Surface observations
- Release information
- Termination summary
- Meteorological data (decoder & processed)
- Angular or Winds Data
- Calibration Data

2.3.1.1.15 Ascension Number Table

The Ascension Number Table contains information for each release during a calendar year. Ascension tables are referenced by year. This table will be used to locate information for previous flights and to keep track of flights that should be or have been archived. WsART will have the capability of bridging years when examining ascension logs. This is essential when processing the first few flights of a new year as the ascension log will contain the information necessary for retrieving the previous flight information. The ascension table will contain the following information for each ascension and release in a calendar year:

- Ascension number
- Release number (1, 2, or 3)
- Observation date and time
- Lowest pressure reached
- Highest altitude reached (PTU)
- Highest altitude reached (Winds)
- Whether or not the release has been archived
- Date and time release was archived
- Data flag with the following values:
    - 1 - Successful release
    - 2 - Successful observation
    - 4 - Release is ready for archiving
    - 8 - Release was locally archived
    - 16 - Release was network archived
    - 32 - Archiving of release failed due to full disk, data corruption, etc.

The tables in the ascension log are maintained in a list sorted first by ascension number, and then by release number within each ascension.

2.3.1.2 Headquarters Database

For those upper-air sites using WsART, a centralized database containing inventory control information, station data and some flight information will be maintained at the NWS headquarters. The

Headquarter’s database will be an INFORMIX based relational (SQL) database similar to those maintained at each upper-air site. The reason for maintaining the information in a headquarter’s database are to:

- Allow generation of the administrative reports that characterize the entire upper air network.
- Optimally manage WsART site configurations
- Provide a centralized location for controlling site inventory.

2.3.1.2.1 HQ Database Tables Updated by WsART

As part of the headquarters database update process, WsART will be required to provide updated information likely in the form of a transaction log to update specific HQ database tables. WsART will provide updated information for the following HQ database tables.

- Delivery
- Shipment
- Siteinvt
- Flights
- Grdequip

2.3.1.2.1.1 Delivery Table

WsART will generate an update for the delivery table in the HQ database each time a new delivery is received. This update will contain the following information:

- Site ID
- Delivery ID Number
- For Each Sonde Type
  Sonde Type
  Shipment ID
  Date of Delivery
  Quantity Received
- Date the Entry was made
- Name (Initials) of the person who entered the data

2.3.1.2.1.2 Shipment Table

Each time the delivery table is updated, the shipment table must be updated to reflect the changes as well. This table is updated at the same interval as the delivery table. WsART will provide the following information in the update:

- Total received for the shipment and siteid (sum of the quantities received for all records with the specified shipment and site IDs’.

2.3.1.2.1.3 Site Inventory Table (Siteinvt)

WsART will provide updated site inventory information to the headquarters database once each month. The following information will be provided:

- Site ID
- Inventory Report ID

- For Each Sonde Type
  Sonde Type
  Date of the Inventory
  Amount used since the last Inventory
  Number of Rejected Sondes
  Current Balance on hand
- Date the entry was made into the system
- Initials/name of the person entering the data

2.3.1.2.1.4 Flights Table

WsART will update the Flights table in the Headquarters database once perhaps twice a day. The update will contain information relative to the flights performed at a given site. The following information will be provided in the update:

- Site ID
- Date of the Observation
- Ascension Number
- Report ID
- Flight Status
- Sonde Type
- Sonde Serial Number
- Month of the Observation
- Day of the Observation
- Year of the Observation
- Hour of the Observation (UTC. scheduled time, either 00 or 12z)
- Balloon Type
- Balloon lot Number
- Nozzle Lift
- Ascension Rates
  Surface to 400 hPa
  400 hPa to termination
- PTU termination height (meters)
- Termination Reason
- Wind Termination Reason
- Number of minutes of Limiting Angles
- Battery Type
- Battery Lot Number
- Date of Battery Manufacture
- General Remarks
- Observer's Initials
- Name of the person who entered the data
- Date the information was entered into the table.

2.3.1.2.1.5 Ground Equipment Table (Grdequip)

WsART will provide information related to the ground equipment as it changes. This information will change when a calibration of the equipment uncovers an error in ground equipment alignment. These updates will be provided as necessary. The following information will be provided in this update:

- Station ID
- Report ID
- Value of the latest rms
- Date of the last comparison
- Date of the last calibration
- Elevation difference
- Azimuth difference
- Date of the last theodolite test
- General remarks
- Name of the person entering the data
- Date the data was entered into the table

2.3.2 Configuration Requirements

The WsART is designed to be a flexible sounding system whose “look & feel” and operation can be customized to a particular upper-air sites requirements. WsART will provide five different areas of configuration:

- Site Configuration
- System Configuration
- Plot Configuration
- Report Configuration
- Processing Configuration

2.3.2.1 Site Configuration

Each upper-air site will have certain unique parameters such as the station location and altitude to name but a few. These parameters do not change often and are generally entered once when WsART is first installed at a site. WsART will provide access to site specific configuration through a site configuration screen. This screen will be accessible at anytime during an observation but will be password protected.

2.3.2.2 System Configuration

WsART will be required to provide the ability to set and change the configuration of the workstation and its associated hardware. The parameters set in the system configuration file generally do not change often and will not be accessible to the general user. The system configuration will be modifiable in WsART through a password protected system configuration window. The information contained in this window will include device mappings, serial port numbers for peripheral devices, and database access logs to mention but a few.

2.3.2.3 Plot Configuration

WsART will be required to providing graphical plots of the meteorological and wind data. In addition to a series of fixed plots such as the “Skew-T”, many plots created by WsART will be configurable by the observer. WsART will allow the observer to choose the parameters for display on both the X and Y axis, choose the frequency of the parameters being displayed, and overlay multiple plots. Standard plot configurations will be defined for WsART, and the operator through menu choices will able to choose the contents, frequency, and the overall look of the graphics generated by WsART.

2.3.2.4 Report Configuration

Custom tabular reports are a required feature for WsART. WsART will be required to create a series of “fixed” or non modifiable tabular displays for the data stream. In addition to these “fixed” displays, WsART will allow the observer to create custom tabular displays of the data for viewing by selecting the parameters to display in the tabular window from a list.

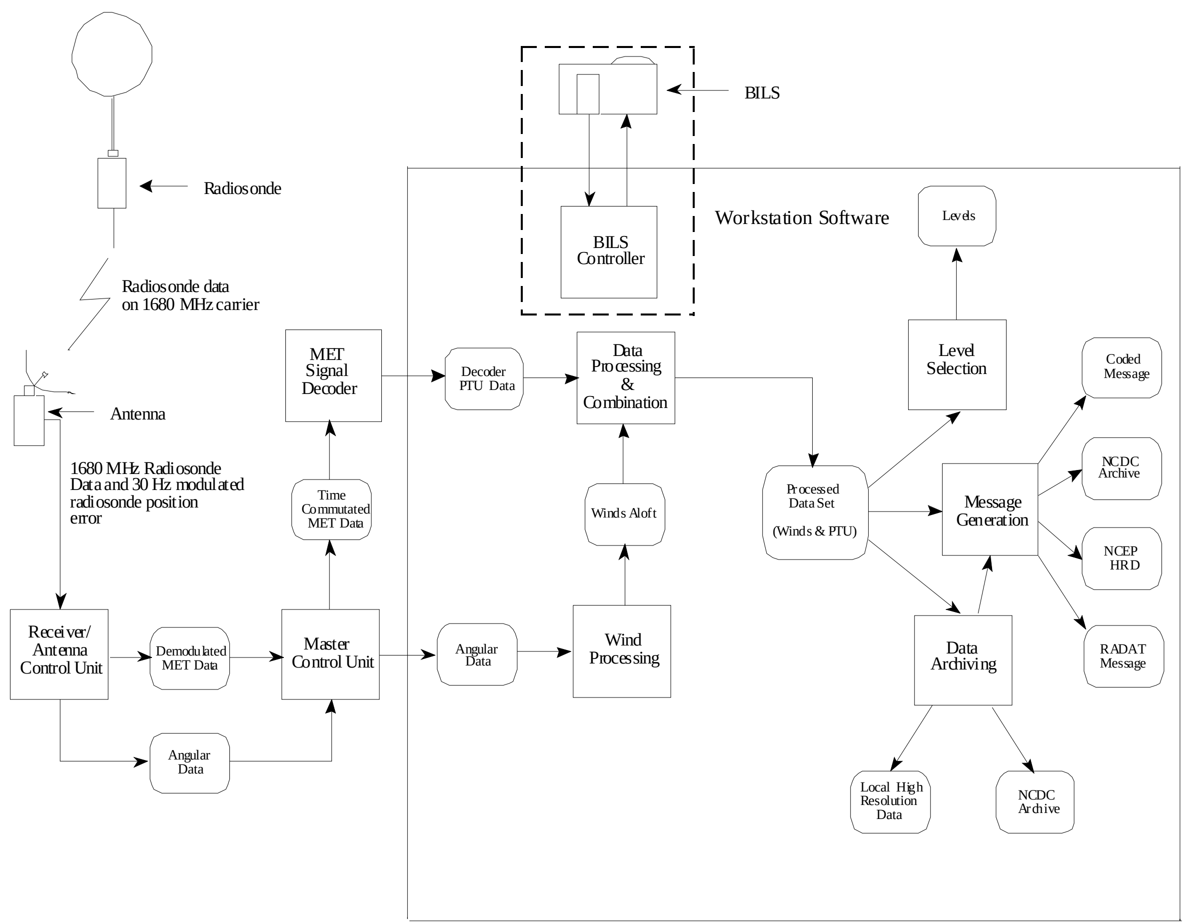
2.3.2.5 Processing Configuration

Certain processing features of WsART will be configurable. These values include the reporting interval of the radiosonde data, smoothing interval, termination processing, limits for missing relative humidity, temperature, and pressure, baseline average interval, etc. The processing configuration values will be maintained in the local database and be accessible through the utilities menu in WsART.

3. Data Acquisition and Processing Requirements

This section describes the requirements for data acquisition, storage and processing, and specifically delineates the types of data, the contents of the database tables, and the computations performed during an observation. It also provides the requirements for acquiring and analyzing the PTU data provided by the MET decoder. In addition to these requirements, a list of normal flight events/anomalies that may occur during an observation have also been included in this section. The flow of data in WsART is detailed by Figure 3-1.

Figure 3-1 : WsART Data Flow Diagram



3.1 Meteorological Data Acquisition

Meteorological data refers to the atmospheric conditions measured by sensors on the radiosonde. This is ordinarily pressure, temperature, and humidity. WsART is required to control and acquire meteorological data from the MET decoder.

The telemetry signal from the radiosonde is processed by the MET decoder to obtain telemetered data values. Meteorological data values are computed in the decoder from the telemetered data by applying a transfer function. This transfer function typically requires coefficients that are unique to each sensor.

To obtain calibrated meteorological measurements, the decoder must have access to the calibration coefficients for the sensors on the radiosonde. For some radiosondes, usually digital radiosondes the calibration coefficients are stored on the radiosonde and transmitted to the decoder in the telemetry stream. For other radiosondes the calibration coefficients are provided on separate media.

For radiosondes where calibration data are provided on separate media WsART will provide a method for loading calibration data onto the workstation disk. It will also locate and provide calibration data to the decoder, and save a copy of the calibration data with the detailed flight data.

WsART will acquire and record time, pressure, uncorrected temperature, relative humidity, and any auxiliary channel data from the decoder. The observer shall be able to suppress acquisition and storage of auxiliary channel data. The raw data acquired from the decoder is processed, corrected, and smoothed to form the Processed Data Set (PDS).

3.1.1 Constructing the Processed Data Set (PDS)

The PDS is the basis for all products generated by WsART. The processed data are derived by first applying pressure and temperature corrections to the raw data, and then smoothing algorithms to the corrected data. Levels are selected from the PDS, the coded messages are generated from the PDS, and the RADAT message is generated from the PDS. WsART will use the following procedure to create the PDS.

- Acquire the raw PTU values from the decoder. The raw values acquired by WsART are time, pressure, uncorrected temperature, relative humidity, and any auxiliary channel data. These data are often referred to as the raw data set.
- Apply the pressure correction to the raw data. WsART will record and maintain both raw and corrected pressure values.
- Generate the corrected data set by applying the vendor supplied correction algorithms. (Currently only correction is temperature correction for solar radiation)
- Apply a least squares (LS) quadratic smoothing/averaging algorithm to remove outliers and create the resulting processed data set. A quality indicator will be assigned to the PDS data values at this point.

3.1.2 Time

The time value for each meteorological data point reported by the radiosonde will be stored in the meteorological data table along with the pressure, temperature and humidity. Additionally a time stamp for each angular data reading will be stored along with the elevation and azimuth angles and slant range in the Position Data Table. For WsART, the time-tag placed in the meteorological data file will represent elapsed flight time and have a resolution of tenths of a second.

3.1.3 Pressure

Pressure will be recorded to the nearest hundredth of a hPa for all pressure measured during the observation. The surface pressure at time 000.00 will be corrected for the pressure at the release point (part of the station data table), and for any discrepancy noticed during radiosonde baselining. These corrections will be added algebraically to the surface pressure as entered by the observer in the administrative data table. The allowable range of pressure values in WsART will be 1070.00 hPa to .01 hPa.

Additionally, they will be adjusted for the pressure difference between the surface pressure and the release point pressure due to altitude differences between the station sensor and the radiosonde release point. The formula for this pressure correction is defined in

3.1.4 Temperature

WsART will record temperature to the nearest tenth of a degree Celsius. Temperature values of less than zero will be prefaced by a minus sign while a temperature of 0.0°C or higher will be unsigned. The valid range of temperature values from the radiosonde is -100.0°C to 50°C.

3.1.5 Relative Humidity

WsART will record relative humidity values from the radiosonde to the nearest tenth of a percent for all humidities measured during the observation. The valid range of humidities recognized by WsART is 0.0% to 100.0%.

3.1.6 Meteorological Data Sources

WsART will be required to acquire meteorological data (pressure, temperature, and humidity) from several sources during an observation. The meteorological data sources for WsART are:

- MET Decoder
- Observer Entered Values

3.1.6.1 MET Decoder

The radiosonde meteorological data are acquired by sensors on the radiosonde and transmitted to the ground in the radiosonde telemetry. Although the same basic parameters are measured by all radiosonde systems, there will be variations in the interface requirements for each specific decoder.

Basically, the decoder will provide the WsART workstation with time stamped Pressure, Temperature, and Humidity values. It may also provide auxiliary channel data such as quality indicators.

3.1.6.2 WsART Requirements for Processing Decoder Data

For all data supplied to WsART by the decoder, WsART will be required to:

- Acquire and store the data received from the decoder at the highest reporting rate of the radiosonde.

3.1.6.3 Observer Entered Observations

In addition to the data provided by the decoder, there are certain data not available automatically that are required as part of an observation. Information such as the surface observation, cloud height, cloud type, and sky cover are entered by the operator as part of the pre-flight sequence.

These values are required as part of the coded message generation.

3.1.7 Assigning Quality (Q) Indicators

WsART will be required to assign Q Indicators, smooth the PTU data, and perform outlier removal/adjustment on the PTU data retrieved from the decoder. The WsART technique for assigning Q Indicators to the data stream involves fitting a least square (ls) fit to each PTU value across a short time interval (configurable). The standard deviation encountered during the fit will be the Q Indicator assigned to the data value. This standard deviation is used as a measure of data integrity.

3.1.8 Analyzing Meteorological Data

The current requirements for this have not yet been defined. However, WsART will be designed such that addition of analysis options will require only minor changes to the software. Note that all variables/parameters listed will be made configurable unless otherwise noted.

3.1.8.1 Determining Valid Meteorological Data

WsART will be required to determine valid meteorological data. To identify valid meteorological data, WsART will perform a series of checks on the data. It is during these checks that questionable or bad data are identified and marked as such. It is important to note that while these checks will be implemented in WsART, no data will be deleted or modified automatically by the software. Rather, WsART will notify the observer of the bad or questionable data and allow them to take whatever action they deem appropriate. The following checks and quality control will be performed by WsART in order to determine valid data:

- Data Plausibility Check
- PTU Gross Limits Check
- Element Profile Quality Control
  Super adiabats
  Inversions
  Large Element Shifts
  Ascension Rates
  Miscellaneous Checks
- Surface Observation Quality Control
- Temporal/Time Quality Control
  Excessive Temperature Change
  Excessive Height Change

3.1.8.1.1 Data Plausibility Check

WsART will perform a data plausibility check on the level quality, elapsed time, pressure, humidity, dew point depression, wind direction, and type level. Any field found to be out of range, will be flagged as Recommend Reject by WsART. Q Flag value 40 will be assigned if the valid is below the lower limit and Q Flag value 41 will be assigned if the value is above the upper limit. Please refer to Table B-1 for a complete description of the WsART Q/C Flags. Table 3-1 shows the data plausibility checks for WsART.

Table 3-1: Data Plausibility Checks (Ref: NCDC)

Field	Valid Range
Elapsed Time	0 to 120 minutes
Pressure	1070 hPa to .01 hPa
Height	-50 to 45,000 meters
Temperature	-100°C to 50°C
Relative Humidity	0 to 100%
Dew Point Depression	-135°C to 35°C
Wind Direction	0.01 to 360
Surface Pressure	Greater than all levels aloft
Azimuth Angle	0.1 to 360°
Elevation Angle	-5.0° to 90.0°

3.1.8.1.2 PTU Gross Limits Check

WsART will check the processed data values for height, temperature, and humidity against a series of gross limit checks. These checks are done at specified heights or levels during the observation. During these checks the data are classified as either good, bad, or questionable. Three ranges are defined and how the data are classified depends on which range the data falls into. Values in the low and high good range are considered good data. Values below the low good range but above the reject low range or above the high good range but below the high reject range are considered questionable. Values above the high questionable range or below the low questionable range are considered bad. Table 3-2 and Table 3-3 show the gross limits for height and temperature in WsART.

Table 3-2: Gross Height Limits (meters) (Ref: NCDC)

Pressure Level (hPa)	Low Reject	Low Suspect	High Suspect	High Reject
1060	-100	-50	410	700
1000	-100	-50	410	700
850	200	800	1700	2050
700	1900	2400	3350	3600

Table 3-2: Gross Height Limits (meters) (Ref: NCDC)

Pressure Level (hPa)	Low Reject	Low Suspect	High Suspect	High Reject
500	4300	4710	5890	6300
400	6100	6510	7690	8100
300	7500	8080	9720	10300
200	9800	10520	12580	13300
150	11400	12200	14500	15300
100	13500	14430	17070	18000
70	15400	16450	19450	20500
50	17300	18450	21750	22900
30	20500	21770	25430	26700
20	23000	24440	28560	30000
10	27200	28600	32600	34000
7	29800	31160	35040	36400
5	32200	33560	37440	38800
3	35300	36760	40940	42400
2	38400	40110	44990	46700
1	41700	43670	49330	51300

Table 3-3: Temperature (degrees C) (Ref: NCDC)

Pressure Level	Low Reject	Low Suspect	High Suspect	High Reject
1060	-70.0	-50.0	45.0	50.0
1000	-70.0	-50.0	45.0	50.0
850	-70.0	-42.0	32.0	42.0

Table 3-3: Temperature (degrees C) (Ref: NCDC)

Pressure Level	Low Reject	Low Suspect	High Suspect	High Reject
700	-75.0	-38.0	18.0	32.0
500	-81.0	-50.0	-2.0	17.0
400	-73.0	-53.0	-12.0	5.0
300	-75.0	-62.0	-22.0	5.0
250	-79.0	-65.0	-27.0	-9.0
200	-83.0	-68.0	-30.0	-13.0
150	-89.0	-70.0	-34.0	-20.0
100	-96.0	-75.0	-37.0	-28.0
70	-98.0	-80.0	-37.0	-29.0
50	-100.0	-82.0	-37.0	-29.0
30	-98.0	-80.0	-35.0	-26.0
20	-96.0	-77.0	-31.0	-15.0
10	-87.0	-71.0	-22.0	-1.0
7	-80.0	-66.0	-12.0	8.0
5	-76.0	-63.0	-10.0	17.0
3	-75.0	-61.0	-2.0	32.0
2	-76.0	-54.0	8.0	34.0
1	-78.0	-47.0	17.0	32.0

3.1.8.1.3 Element Profile Quality Control

WsART will check for discrepancies by comparing same elements against each other in the vertical. Super adiabats, inversions, large elements shift, ascension rates, and other miscellaneous checks will be performed by WsART during this stage of quality control.

3.1.8.1.3.1 Superadiabatic Lapse Check

Superadiabatic lapse rates occur whenever the temperature decreases more than 0.98°C per 100 meters or 0.0098°C per meter. Supers can occur, but if they exceed 34.2°C per kilometer or 0.0342°C per meter are not likely and will be deemed erroneous.

WsART will flag superadiabatic lapse rates as follows:

<u>For heights < 1 km above ground level</u>

- If the lapse rate > 0.098°C/m but ≤ 0.0342°C/m, the super will be flagged as questionable (Q Flag value 21).
- If the lapse rate > 0.0342°C/m the super will be flagged recommend reject (Q Flag value 43).

<u>For heights > 1 km above ground level</u>

- If the lapse rate > 0.098°C/m but ≤ 0.0147°C/m, the super will be flagged as questionable (Q Flag value 21).
- If the lapse rate > 0.0147°C/m, the super is flagged as recommend reject (Q Flag value 43).

All stratospheric supers (pressure < 300 hPa) will be flagged as questionable or bad based on how extreme they are according to the above mentioned criteria.

The observer will be alerted (“possible temperature sensor failure”) in the flight anomalies table if the sounding contains 10 or more lapse rates exceeding 0.0147°C/m.

Please refer to Section 10.1.7 for a description of the algorithm used to determine superadiabatic lapse rates in WsART.

3.1.8.1.3.2 Moisture Checks

WsART will flag Relative Humidity data as follows:

- If Relative humidity is determined to be erratic by the least-squares (or similar) filter, Relative Humidity will be flagged as questionable (Q Flag value 27).
- If Relative Humidity is greater than 20% at pressures less than 100 hPa, Relative humidity is flagged as questionable (Q Flag value 26).
- If the first Relative Humidity data point differs more than 15% from the surface Relative Humidity, then Relative Humidity is flagged as questionable. (Q Flag value 25 if RH is below surface RH, Q Flag value 26 if RH is greater than surface RH)

3.1.8.1.3.3 Ascension Rate Checks

WsART will identify and alert the observer of the following quality control problems related to ascension rate.

WsART will calculate geopotential heights from the decoder PTU data at 1 to 3 second intervals.

A running (1 to 3 second) 1 minute height difference will be calculated and the data flagged as follows:

- The PTU data is flagged as recommend reject as if the height difference from minute to minute exceeds 500 meters. (Q Flag value 44)
- The PTU data is flagged as questionable if the height difference from minute to minute is between 450 and 499 meters. (Q Flag value 23)
- The PTU data is flagged as questionable if the height difference from minute to minute is less than 200 meters. (Q Flag value 24. Note that floating balloon criteria overrules this flag)

3.1.8.1.3.4 Miscellaneous Quality Control Checks

WsART will also identify the following miscellaneous conditions:

- If a temperature point is determined to be erratic by the least-squares (or similar) filter, the data is flagged as recommend reject. (Q Flag value 42)

3.1.8.1.4 Surface Observation Quality

WsART will check surface data elements against each other for internal consistency and the observer will be alerted to check the surface observation entry for accuracy if any of the following occur:

- Surface Pressure is less than 750 hPa or greater than 1070 hPa.
- Surface Temperature less than -50°C or greater than +45°C.
- A Superadiabatic Lapse rate which occurs from the surface to the first reported radiosonde temperature.
- The surface temperature is less than the dewpoint.
- If the temperature and dewpoint result in an RH of less than 5%.
- If the RH at the surface and the first RH measurement from the sonde differ by more than 15%.
- If the surface windspeed is greater than 50 knots.
- If fog is reported but the dewpoint depression is greater than 3°C.
- If precipitation is reported, but 3/8 or less cloud cover is reported.
- Frozen precipitation is reported, but temperature greater than 7°C.

WsART will only alert the observer to validate questionable entries. It is assumed that the observer will validate the data entries. No QC flag values other than “blank” will be assigned to the surface weather entries.

3.1.8.1.5 Temporal/Time Quality Control

WsART will during the course of an observation perform quality control checks on the changes in temperature and heights since the last sounding taken.

Any data determined to be questionable will be flagged as such and the actual change (meters or degrees) will be indicated in the flight anomalies table. If the previous sounding from 12 hours ago is not available, these checks will not be made.

3.1.8.1.5.1 Excessive Temperature Changes

Significant warming or cooling in a temperature sounding above 850 hPa compared against the previous sounding can indicate possible problems with the radiosonde temperature sensor. WsART will perform a series checks in order to identify possible instrument problems. WsART will flag temperature data as questionable (Q Flag value 30) if the thresholds in Table 3-4 (Ref: USAF handbook on Geophysics and Space Science, 1985) are exceeded.

Table 3-4: Excessive Temperature Changes

Mandatory Level	Questionable (QC Flag 30) Temperature threshold
700 to 150 hPa	>10°C
100 to 3 hPa	> 7°C

3.1.8.1.5.2 Excessive Height Change

Geopotential heights above 850 hPa changing rapidly from one sounding to the next may be indicative of a temperature sensor and/or pressure sensor failure.

WsART will check the change in pressure heights from the current observation to the observation 12 hours ago. Changes in the surface station pressure will dictate threshold height differences aloft. These threshold holds are shown in Table 3-5. Differences exceeding the values are flagged as questionable (Q Flag value 30).

Table 3-5: Height change from flight 12 hours ago

Surface Pressure Change (SPC)	Surface to 700 hPa	700 - 400 hPa	400 -100 hPa	100 hPa - Term
0 < SPC < 5	> 45	> 70	> 100	> 175
5 < SPC < 10	> 90	> 130	> 180	> 200
10 < SPC < 20	> 160	> 200	> 250	> 300
SPC > 20	---	> 200	> 250	> 300

3.1.8.2 Locating Missing Meteorological Data

WsART will be required to identify or locate a stratum of missing data during data acquisition and processing. WsART will identify missing data if:

- The MET Decoder provides missing data for greater than 1 minute.
- During outlier removal if more than one consecutive minute of data values is thrown out, the processed data is set to missing. If the duration of missing data is less than one minute, the missing values are interpolated by WsART.

QC Flags for missing data are described in Appendix B. Please refer to Table B-1 for a complete description of the QC Flags for WsART.

3.1.9 Derived Quantities

During meteorological data acquisition, WsART will be required to derive a series of values from the meteorological data being acquired. The following parameters or values will be calculated by WsART.

Geopotential Height:	WsART must compute for each data point, the geopotential height of the radiosonde. This value is reported in units of scaled geopotential above mean sea level. The geopotential is defined as the potential energy due to gravity of a unit mass of air at some point; above a standard position (i.e. zero energy), usually mean sea-level, and is measured in a positive sense vertically. The geopotential height calculated is defined in Section 10.1.2 of this document.
Dewpoint Depression:	The dewpoint depression is defined as the difference between the ambient air temperature and the dew point temperature. WsART will be required to compute the dewpoint depression for each meteorological data point acquired during an observation. The formula for calculating the dewpoint is listed in Section 10.1.6.

3.2 Identification of Flight Events and Anomalies

It is critically important to recognize flight events, meteorological phenomena, and data anomalies as they occur in a sounding in order to avoid misinterpreting data transmission. Certain flight events can sometimes appear to represent one condition when, after additional monitoring, it becomes obvious that the data represent the occurrence of something else. WsART will detect and notify the observer of the following anomalies as they occur in an observation:

- Balloon burst
- Floating balloon
- Large ascension rate changes
- Large superadiabatic lapse rates
- Descending/Reascending balloon
- Pressure sensor failure
- Temperature sensor failure
- Relative humidity sensor failure
- Excessive temperature and height changes
- Excessive missing data
- System malfunctions

Both audio and visual alerts will be provided by WsART when the flight events and anomalies are identified. Alert types are configurable to be either on or off. Additionally, the type of audio alert used in WsART will be configurable.

3.2.1 Balloon Burst

WsART will be required to identify the balloon burst. The balloon burst point can be identified when a trend in the pressure changes from diminishing to a trend of little change or increasing pressure. WsART will detect a balloon burst for the following conditions:

- Pressure constantly increases over 1 minute and changes more than 2 hPa.

For cases in which a loss of signal occurred at balloon burst, the terminating pressure will be the lowest measured pressure.

WsART will upon detection of the balloon burst provide both an audio and a visual alert to the observer. This visual alert will contain a message indicating the detection of the balloon burst, and the time of the detection.

3.2.2 Floating Balloon

WsART will be required to detect a floating balloon (Q Flag value 20). A floating balloon can be identified when little or no change in pressure is noticed over time. WsART will detect a floating balloon for the following conditions:

- No more than 10 hPa change in pressure over a five minute period for pressures greater than or equal to 100 hPa.
- No more than 2 hPa change in pressure over a five minute period for pressures between 100 hPa and 10 hPa.

When a floating balloon is detected, WsART will notify the operator through the display of both an audio alert and a visual alert. The visual alert will contain a message notifying the observer that a floating balloon was detected and terminate the flight.

3.2.3 Large Ascension Rate Changes

WsART will display both an audio alert and visual alert notifying the observer of the large ascension rate change. For a description of the WsART method of determining large ascension rate changes refer to Section 3.1.8.1.3.3.

3.2.4 Large Superadiabatic Lapse Rates

For a description of superadiabatic lapse rate detection and identification in WsART, refer to Section 3.1.8.1.3.1.

3.2.5 Descending/Reascending Balloon

WsART will be required to identify a descending/reascending balloon. A balloon that ascends, descends, then reascends again (e.g., during icing conditions) is identified by analyzing the trend in pressure measurements reported by the radiosonde. WsART will identify a descending/reascending balloon for the following condition:

- The pressure readings change from decreasing to increasing for at least 0.5 minute followed by decreasing pressures for a period of time equal to the time that the balloon was descending (pressure increasing). The rate of change of pressure between the balloon ascent and descent is approximately equal, and is only about one third as great as that for balloon burst.

The type of descending/reascending event described above occurs only at pressures greater than 400 hPa where icing and significant downdrafts occur. WsART will display an audio alert and a visual alert notifying the observer of the event. The visual alert will contain a status message indicating that a descending/reascending balloon has been identified.

During descending/reascending balloon states, WsART is required to insert missing data values (99999) for elevation data. Missing data values will be inserted for the duration of the descending/reascending balloon up to but not including the point at which the balloon reaches an altitude “higher” than when the balloon started descending.

3.2.6 Pressure Sensor Failure

WsART will be required to identify the failure or suspected failure of the radiosonde pressure sensor. A pressure sensor failure is suspected when a loss of signal occurs or sensor dropouts cause a number of sampling points to be missing. WsART will identify a pressure sensor failure (Q Flag value 49) for the following condition:

- If more than 10 <u>consecutive</u> minutes of pressure sampling points are missing.

WsART will be required to terminate a flight if a pressure sensor failure is detected. The flight will be terminated at the last usable point in the flight and the termination reason will be set to pressure sensor failure. WsART will display both an audio and a visual alert to the observer indicating the sensor failure.

3.2.7 Temperature Sensor Failure

WsART will be required to identify the failure or suspected failure of the radiosonde temperature sensor. WsART will identify a temperature sensor failure (Q Flag value 49) for the following conditions:

- Temperature changes of more than 0.5°C from one-second to one-second average over a period of two minutes.
- If temperature values in the meteorological data file do not change by more that $\underline{+}$0.5 °C over a 3-minute period.
- If more than 3 <u>consecutive</u> minutes of temperature sampling points are missing.

WsART will be required to terminate a flight if a temperature sensor failure is detected and the amount of missing or recommend reject data exceeds requirements. The termination reason will be set to temperature sensor failure, and WsART will display both an audio and a visual alert indicating the sensor failure. For more information relating to temperature checks in WsART refer to Section 3.1.8.1.5.1.

3.2.8 Relative Humidity Sensor Failure

WsART will be required to identify the failure or suspected failure of the radiosonde humidity sensor. A humidity sensor failure can be identified by analyzing the relative humidity readings from the radiosonde. WsART will identify a humidity sensor failure (Q Flag value 49) after the following conditions:

- If 25 or more consecutive minutes of humidity readings are greater than 90%
- If 10 or more consecutive minutes of humidity readings from the 400 hPa level to termination are greater than 80%.
- If the RH remains constant at 1% or less for more than 15 consecutive minutes from surface to 300 hPa.

If the RH sensor fails, WsART will be required to continue the flight to termination. For more information relating to checks performed on the RH data refer to Section 3.1.8.1.3.2.

3.2.9 Excessive Missing Temperature and Height Changes

WsART will alert the observer to excessive changes in temperature and height from the sounding taken 12 hours earlier.

See Section 3.1.8.1.5 for the threshold values and associated QC Flags.

3.2.10 Excessive Missing Data

WsART will be required to detect and terminate an active flight due to excessive missing data. The amount of missing data considered excessive depends on the data type (pressure, temperature) and will a configurable option in WsART. Any missing data (PTU and winds) continuing for more than 1 minute will result in an audio alert. All missing data will be assigned a QC flag (Q Flag values 01 to 19). If the reason for the missing data can not be determined, then Q Flag value 19 will be used.

3.2.10.1 Excessive Missing Data Frames

WsART will monitor the PTU data stream and alert the observer of missing data frames. Missing data frames occur when no Temperature, Pressure or Relative Humidity values are supplied for a sampling period. WsART will terminate a sounding for missing data frames under the following conditions:

- If more than 3 <u>consecutive</u> minutes of Pressure, Temperature and Humidity sampling points are missing.

3.2.10.2 Excessive Missing Temperature

WsART will terminate a flight due to excessive missing temperature if the amount of missing temperature exceeds the following thresholds:

- Surface to 10 minutes 4.0 minutes
- Surface to 25 minutes 6.0 minutes
- Surface to 60 minutes 12.0 minutes
- Entire flight 16.0 minutes

3.2.10.3 Excessive Missing Pressure

WsART will terminate a flight due to excessive missing pressure if the amount of missing pressure exceeds the following thresholds:

• Surface to 10 minutes	4.0 minutes
• Surface to 25 minutes	10.0 minutes
• Surface to 60 minutes	24.0 minutes
• Entire flight	40.0 minutes

3.2.11 System Malfunctions

Because of the difficulty in describing every type of possible system malfunction, no specific requirement will be stated in this area. However, because the WsART software is predicated on the fact that the system will acquire and process both radiosonde and position data, a minimum requirement will be that if the WsART malfunctions or power is terminated in some way, WsART will have the capability of replaying the flight up to the malfunction.

3.3   Calculations

As part of an observation or rework, WsART performs a series of calculations. The calculations performed by WsART are defined in Section 10.

4. Wind Data Acquisition and Processing

In WsART the existing RDF tracking system used in MicroART will provide the position data (elevation and azimuth angles). This position data is collected through the Master Control Unit (MCU) printer port by the acquisition task, and transformed into winds aloft by the processing routines. The WsART wind acquisition and processing scheme is as follows:

- Acquire Position Data from the MCU printer port.
- Analyzing the Azimuth & Elevation Angular Data
- Convert Angular Data to X, Y, and Z Coordinate Data.
- Smooth X, Y, Z Coordinate and Convert to Wind Speed and direction, U and V, and Lat/Lon.

4.1 Angular Data Acquisition

WsART will acquire the angular data values (elevation and azimuth angles) every six seconds from the RDF unit via the MCU printer port. As the data values are acquired, the acquisition software applies the orientation correction and stores the values in the position data table.

4.1.1 Radiotheodolite Tracking Data

The RDF is a ground based tracking system. It tracks the position of the radiosonde from a ground based antenna using radio direction finding techniques. This type of system provides the orientation of the radiosonde relative to the release site, but does not compute wind speed or direction. (For WsART the software will be required to compute the winds data.)

The Radiotheodolite or ground tracking system provides angular data from which WsART will compute the radiosonde location and winds data for the observation.

4.1.1.1 Angular Data

Angular data refers to the antenna position, and specifically includes elevation and azimuth angle data. These data will be the actual measurements acquired by WsART. As WsART acquires the elevation and azimuth angles from the RDF system, it will be required to store the values in the position data table in the local data base.

The elevation angles will be in the range of -5.00° to 95.00° inclusive, and the azimuth angles will be in the range of 0.00° to 360.00° inclusive. The lower range for elevation angles will be a configuration item in WsART and the initial value will be set to -5.00°.

4.1.2 Orientation Correction

As part of the pre-flight sequence, WsART will determine if the angular data reported by the RDF requires an orientation correction. Determining the orientation correction involves aiming the RDF antenna at a known position during pre-release and noting any difference in the reported position with respect to the actual position. Any discrepancy noted must be added to the acquired angular data and is referred to as an orientation correction. WsART perform the orientation check as part of pre-release. The orientation correction will be applied to the raw angular data prior to windfinding.

Note that the values stored in the position data table will not be the true raw angular data values but rather will be the angular data values with the orientation correction applied. Since the orientation correction is a known value and will be stored with the pre-flight information as part of the permanent flight record, the correction values could be “backed out” for research purposes if need be.

If the orientation correction required is greater than 0.5^o (system configurable parameter), WsART will display a message to the observer indicating the discrepancy and mentioning that the system might need maintenance. The observer will be given the option of continuing with winds processing in which case, an event will be logged to the flight record indicating that the observer acknowledged that the equipment was out of tolerance but continued processing the winds. If the observer chooses not to continue because of the orientation discrepancy, WsART will allow the observer to either terminate the pre-release sequence or continue the observation without processing the winds data.

4.1.2.1 Specific WsART Requirements for Position Data Acquisition

- WsART will acquire angular data from the RDF system at the highest available rate which is currently once every six seconds.
- WsART will store the angular data values in the position table of the local database.
- WsART will compute the winds from the angular data values in the position data table. The method used to compute the position and winds is a modification of the UCAR (STORM) windfinding technique developed at Sterling, VA.
- WsART will be required to acquire the following specific values from the ART tracking system during an observation: Time of the tracking data relative to the release signal, azimuth and elevation angles, and the tracking status when available.
- WsART will record and store all angle data including that below the limiting angle in the position data table. Angles marked as limiting will not be used in wind computations.

4.2 Analyzing Angular

WsART will acquire position data from the RDF system via the MCU printer port. Some or all of the position data reported by the RDF may be invalid or missing or below the limiting angles. WsART will be required to analyze the position data as it is acquired to determine the validity of the data.

4.2.1 Identifying Valid Angular Data

WsART will acquire and store in the position data table, position data from the RDF system up to and including the point at which the flight terminated. WsART will identify the position data as invalid and mark as missing for the following conditions:

- If either the azimuth or elevation angle is invalid, the other is considered invalid automatically.
- If the data components are out of range. The following ranges are used in WsART:

Elevation 100ths:	0	to	99
Elevation Degrees:	-5	to	95
Azimuth 100ths:	0	to	99

Azimuth Degrees:	0	to	360
Range Meters:	0	to	500,000

4.2.2 Identifying Missing Angular Data

WsART will continue to report all poor/bad angle data and will identify and mark data as missing for the following case:

- If the balloon descends, then reascends past the first ascent, WsART will insert missing angular data values in the position data file. These missing values will not be used in the wind calculations.

If angular data are missing for less than one minute, WsART will be required to interpolate the missing data. The interpolated range of data will be marked in the position data table.

4.2.2.1 Identifying Questionable Angular Data

Position data reported by the RDF system may be considered questionable under a number of circumstances and conditions. WsART will identify and possibly mark as missing questionable position data from RDF tracking system for the following cases:

- Erratic Angular Data
- Failure of Angular Data Checks
- Balloon Overhead
- Limiting Angles

4.2.2.2 Erratic Angular Data

WsART will be required to check for and identify erratic angular data. WsART will check for erratic angular data just as MicroART does. These erratic angular data checks are under discussion and changes are subject to direction from OSB meteorologists. Any erratic angular data will be flagged as Q Flag value 42.

4.2.2.3 Angle Checks

WsART will examine the angular data checking for reasonable values (within -5.0° to 90° for elevation and 0° to 360° for azimuth). All angles will be checked except those that bound missing ranges of angular data. The angles are checked in overlapping groups of five angles with elevation and azimuth angles checked independently. Within each group of five angles, the third or middle angle is checked based on the trend of the other angles. There are three possible trends: a straight line, a curve, and a peak. If the angle does not conform to the trend, the suspect angle may be questionable (Q Flag value 27) and the observer is alerted to check the angle. During the angle checks no data are marked as missing. Rejecting of this data is left to the observer.

4.2.2.4 Balloon Overhead

WsART will identify data as questionable when the balloon tracks directly over the radiotheodolite antenna. The balloon overhead case can cause the tracking antenna to lock-up and thus must be identified. For WsART to identify the balloon as overhead, any or all of the following conditions must be satisfied:

- The event must occur during the first 15 minutes of the flight.
- The elevation angles must be greater than 80°.
- The azimuth angles have changed by more than 100° from one whole minute to the next.

When any or all of the above requirements are met, WsART will be required to mark the angular data as recommend reject (Q Flag value 48).

4.2.2.5 Identification of Limiting Angles

The station data table in WsART will contain a table of limiting angles. WsART will be required to use the values in this table to detect if the angular data reported by the sonde is below the limiting angle. Whenever the elevation or azimuth angles exceed the boundaries specified in the limiting angles table, WsART will identify the data as limiting (Q Flag value 50) and not include those values in wind computations. Any data flagged as limiting will not be removed from the DDS however.

4.2.2.6 Conversion of Angular Data to Rectangular Coordinates (X,Y,Z)

Once the angular data has been checked and identified for missing, questionable, reject and limiting angles, the values are then converted from angular data to rectangular coordinates. After the conversion, the Latitude and Longitude values are computed from the rectangular coordinates.

In addition to the angular values (elevation and azimuth angle), the height of the radiosonde is required in order to calculate the rectangular coordinates. This value is reported by the radiosonde in Geopotential height and must be converted before being used in the calculations.

Once the angular and height values are converted to X, Y, and Z, they are used to calculate the latitude and longitude for each point in the flight. Refer to Section 10.2 of this document for a description of the formulas used for X, Y, Z, and latitude and longitude.

4.3 Determination of Winds

The final phase of wind determination is the calculation of wind speed and direction and the U and V wind components. These values will be computed by WsART from the rectangular coordinates (X,Y, and Z) computed earlier and stored in the position data table. A least squares smoothing, interpolation and outlier removal technique similar to the one employed by NEXUS will be applied to the data at this point in the wind calculations. The result will be wind speed and direction and smoothed U and V wind components. These values will be stored in the wind data table in the local database. The wind speed will be stored to the nearest knot, and the wind direction will be stored to the nearest whole degree. Wind values will be extrapolated when not enough data are available to compute the actual winds such as at termination.

4.4 Editing of Angular Data

WsART will allow the observer at any time during an observation to edit the RAW angular data values (azimuth and elevation) in the position table. Editing of the position data constitutes removing or marking as unusable values and restoring previously removed values. Editing of the angular data causes WsART to reprocess the wind values.

4.5 Editing of U and V Wind Components

WsART will allow the observer at any time during an observation to edit the U and V wind components stored in the wind table. Editing of the U, V values constitutes removing or marking as unusable values and restoring previously removed values. Editing of the U, V values causes WsART to reprocess the wind values.

4.6 Wind Quality Control

WsART will check all wind values for gross limits and vertical discontinuity, i.e., an abrupt increase/decrease in speed or an abrupt change in direction.

4.6.1 Wind Gross Limits Check

WsART will check wind speed at each level against the gross limits listed in the table below. Good wind values will fall in below the high suspect value. Questionable winds will fall below the high reject and above the high suspect. Values above the high reject are considered bad. Table 4-1 shows the gross limits for winds.

Table 4-1: Wind Maximum (m/sec) (Ref: NCDC)

Pressure Level	High Suspect (QC flag 26)	High Reject (QC flag 45)
1060	25.0	60.0
1000	25.0	60.0
850	35.0	70.0
700	45.0	80.0
500	70.0	110.0
400	85.0	140.0
300	100.0	160.0
250	105.0	170.0
200	100.0	160.0
150	100.0	150.0
100	85.0	130.0
70	70.0	120.0
50	75.0	130.0
30	80.0	130.0
20	90.0	130.0

Table 4-1: Wind Maximum (m/sec) (Ref: NCDC)

Pressure Level	High Suspect (QC flag 26)	High Reject (QC flag 45)
10	105.0	140.0
7	115.0	150.0
5	125.0	170.0
3	155.0	210.0
2	170.0	220.0
1	180.0	220.0

4.6.2 Wind Speed Changes from Minute to Minute

WsART will check the wind speed values against the wind speed value immediately preceding them and classify the speeds as specified in Table 4-2 .

Table 4-2: Wind Speed Changes (kts) (Ref: MicroART)

Interval (mins)	Good	Questionable (QC flag 28)	Reject (QC flag 46)
1	< 28	28-49	> 49
2	< 45	45-65	> 65
> 3	Not Checked	Not Checked	Not Checked

4.6.3 Wind Direction Changes from Minute to Minute

WsART will check each wind direction against the direction immediately preceding it and will classify the wind directions as specified in Table 4-3 .

Table 4-3: Wind Direction Change (degrees) (Ref: MicroART)

Interval (mins)	Speed (kts)	Good	Questionable (QC flag 29)	Reject (QC flag 47)
any	< 20	any	---	---
1	20-30	< 36	36-44	> 44
2	20-30	< 51	51-59	> 59
1	31-39	< 31	31-39	> 39
2	31-39	< 46	46-54	> 54

Table 4-3: Wind Direction Change (degrees) (Ref: MicroART)

Interval (mins)	Speed (kts)	Good	Questionable (QC flag 29)	Reject (QC flag 47)
1	40-47	< 26	26-34	> 34
2	40-47	< 41	41-49	> 49
1	48-54	< 21	21-30	> 30
2	48-54	< 36	36-43	> 43
1	> 54	< 16	16-24	> 24
2	> 54	< 26	26-34	> 34
> 2	any	Not Checked	Not Checked	Not Checked

5. Flight Processing Requirements

This section describes the flight processing requirements for WsART. Each section below describes the requirements in as much detail as possible. The flight processing requirements have been organized into the following categories:

- Pre-release Requirements
- Release Sequence Requirements
- Status Display Requirements
- Data Entry and Display Requirements
- Data Analysis Requirements
- Message Generation Requirements
- Level Selection Requirements

5.1 Pre-release Requirements

Prior to balloon release, WsART will perform a series of pre-flight events. The following events will occur during the WsART pre-release phase:

- Equipment Check and Initialization
- Pre-Flight Data Entry and Validation:
- Administrative Data Entry
- Flight Equipment Data Entry
- Surface Observation Data Entry
- Baselining

These pre-flight events are grouped into a common sub-menu and all events must occur prior to balloon release. The options in the pre-flight menu will be able to occur in a semi-random order. Semi-random in this sense means that the options cannot be skipped when going forward through the sequence. However, once a pre-flight event has occurred, the operator can choose to return to that option or any other option to re-enter/change fields.

5.1.1 Equipment Check and Initialization

Prior to balloon launch it is of paramount importance that WsART initialize and ensure the correct operation of all hardware components. To do this, WsART will as part of the pre-release phase perform a series of equipment checks and initializations. The checks/initializations performed are as follows:

- Radiotheodolite Orientation Check **-** This check ensures the correct operation of the RDF tracking equipment.
- MET Decoder Initialization and Check - This check and initialization ensures that the serial connection to the decoder is operating correctly, the decoder hardware is operating correctly, and the decoder is initialized correctly.

The observer will be alerted of any errors detected during the equipment checks. Both an audio and a visual alert will be displayed for the observer should an error occur.

5.1.2 Pre-Flight Data Entry and Validation

Prior to performing a sounding, information relating to the sounding such as the observers name, the ascension number, and the flight equipment used must be entered and validated. The following sections describe the entry and validation of the pre-flight data for WsART.

5.1.2.1 Administrative Data Entry

Administrative data entry is an important part of the pre-release sequence. During this step, administrative information pertinent to the observation will be entered or confirmed by the observer. The operator will be prompted to enter administrative and/or validate default values provided by WsART. Information such as Time of the observation, Observer name, ascension number, release number and special observation are some of the administrative values available for observer validation or entry. Refer to Section 6.6.1 for a complete description of the Administrative Data Window.

5.1.2.2 Flight Equipment Data Entry

After the administrative data has been entered, WsART will prompt the observer for information relating to the flight equipment for the observation. Information such as balloon type and size, and radiosonde type and serial number are specified in this window. This window is the second window raised during the pre-flight sequence. Refer to Section 6.6.2 for a complete description of the Flight Equipment Data Window.

5.1.2.3 Surface Observation Data Entry

This window displays the current readings from the observer entered values for the surface observations. This window allows for entry and editing of the official surface observation data. Surface observation data may be entered manually.

All fields in the surface observation window must contain an entry. WsART will prompt the operator if entries are missing in the surface observation window.

WsART will time-tag the data entered in the surface observation window. If the data has not been entered within 10 minutes of the balloon release, WsART will display a dialog box prompting the operator to verify/change the values in the surface observation window.

The surface observation window may be displayed at any time before, during or after the observation and the values in the official surface observation can be edited at any time up to when the data message are transmitted. A correction would need to be applied if the surface observation is modified after the messages are transmitted. Refer to Section 6.6.3 for a complete description of the Surface Data Window.

5.1.2.4 Verification of Pre-flight Data - Administrative, Equipment & Surface

Many fields in the pre-release data screens such as the surface observation values, and the radiosonde serial number are required before the observation can continue. Before a data window is dismissed, WsART checks all required values in the window to see that a value has been entered, and to ensure that the enter value is correct. If WsART detects missing or incorrect values (field size errors or data out of range), a dialog box is displayed notifying the observer of the error. The window is not dismissed, but remains active until the observer corrects the error or elects to cancel.

For surface observation entries, WsART will notify the observer to check the surface observation entries if:

- Pressure is less than 750 hPa or greater than 1070 hPa.
- Temperature is less than -50°C or greater than +45°C.
- Superadiabatic lapse rate which occurs from the surface to the first reported radiosonde temperature.
- Surface Temperature is less than the dewpoint.
- Temperature and dewpoint result in RH less than 5%.
- RH at surface and first RH measurement from sonde differ by more than 15%.
- Surface Wind speed exceeds 50 knots.
- Cloud height reported but no cloud type reported.
- Fog reported, but dewpoint depression is greater than 3°C.
- Precipitation reported, but 3/8 or less cloud cover is reported.
- Temperature above 7°C and frozen precipitation reported.

5.1.3 Radiosonde Baseline Requirements

Baselining involves verifying the operation of the radiosonde, determining the pressure offset, and verifying the operation of the radiosonde's sensors, and associated calibration data as well as frequency. Radiosondes are precalibrated at the factory against known standards for each sensor. Nevertheless, they must be baselined (i.e., calibrated) for the specific observation, prior to their use. Radiosondes are also baselined for checking the electronics. The radiosonde pressure, temperature, and RH used during baseline will be derived from a 15 second running mean. WsART will reject the radiosonde if it exceeds the standard deviation threshold for any of the parameters. The length of the running mean average and the standard deviation thresholds will be configuration options. Refer to Section 6.7.1 for a complete description of the Flight Baseline Control Window.

5.2 Release Sequence and Requirements

The radiosonde release sequence in WsART involves detection and acknowledgment of the radiosonde release signal and verification of successful release.

5.2.1 Release Signal

The WsART observation begins with the release of the radiosonde into the atmosphere. The actual time of release is critical since all sampled meteorological values are referenced against the elapsed time after release. The method for determining balloon release will be a configuration item in the system configuration screen. WsART may automatically detect balloon release. Balloon release will be identified when the MET decoder notifies the WsART software via a signal. Once balloon release is detected, WsART will determine the release time but will allow the observer at any time during the observation to manually change the release time for both the Angular and MET data streams.

5.2.2 Successful Release Requirements

Not all balloon releases will be successful. It is critical that WsART be capable of determining the success or failure of a release. WsART will use the Micro-ART criteria for identifying a successful release. The criteria for a successful release are:

- If the temperature is present for 3.0 minutes of the first 5.0 minutes of the flight.
- Pressure must decrease by at least 5 hPa during the first 5.0 minutes of the flight.

If the above criteria is not satisfied, WsART will display a message for the operator indicating an unsuccessful release. If an unsuccessful release is identified, WsART will terminate the flight immediately.

The amount of pressure decrease and the duration of time specified in the second criteria for successful release will be operator configuration items. The values will default to 5 hPa and 5.0 minutes respectively.

5.2.3 Release Status

WsART will notify the observer of the release status, either an unsuccessful or successful through the release status display. The display is presented when a successful or unsuccessful release is detected and the operator is fed information such as release time for successful release, and a reason if the release was unsuccessful. Refer to Section 6.8 for a more detailed description of the release status.

5.2.4 Adjustment of Release Time

WsART will provide a display window for reviewing and editing the balloon release time. If it is deemed that the release time is not correct, the observer can adjust the reported release time through editing the value displayed in this window.

5.3 Status Display Requirements

WsART will be required to provide a series of status display windows for the observer. These status display windows provide information related to the status of the observation and the hardware components connected to the workstation. Refer to Section 6.8 for a complete description of the Observation Status Display.

5.4 Data Editing and Display Requirements

The WsART software will provide a series of graphical and tabular displays to assist the operator in the analyses and evaluation of unusual events and anomalies. The displays generated will be highly customizable. The WsART software will contain a fixed set of default graphics and tabular displays. The observer will be able to create and save custom graphical and tabular displays to fit the needs of the particular upper air site.

5.4.1 Graphic Displays

The WsART software will be able to display a maximum of four plot windows on the workstation display. Each plot window may contain a different type of plot. The plot windows will be required to follow the MICROSOFT method of tiling windows.

WsART will provide a pre-configured set of graphical displays. The system will also provide the ability to generate custom graphical displays by selecting the fields to be displayed on the X and Y axes, time scale on both axis, logarithmic or linear axis scaling, the line type for the plot (dot, solid, dashed), and the line color. Additionally, WsART will providing for displaying logarithmic plots of the sounding data. All graphical displays will provide the following:

- The ability to zoom (magnify)
- The ability to pan (translate)
- The ability to display grid lines
- Operator selected window sizing
- Automatic window sizing with respect to other plots on the display
- Overlay capability for previous flights

WsART will allow the display of grid lines to be enabled or disabled by the operator. Additionally, if a graphic is zoomed the grid line spacing will be adjusted to maintain approximately the same number of grid lines per linear unit on the display screen. Different zoomed areas of a particular graphic may be displayed simultaneously in separate plot windows.

WsART shall be able to retrieve and display data from previous observations. This includes the display of data from previous observations at the local site at the same time as data from the current observation. WsART will be required to mark or identify in a conspicuous manner, data from other observations to avoid confusion and the number of overlays will be limited to three per graphical display.

WsART will allow the operator to select one or more data points on the graphical display for deletion from the observation. These original measured values will be retained as part of the detailed flight record, and may be restored in a similar manner. Original values deleted in this manner will be marked by a different color and will remain on the screen in case the operator wishes to restore them.

Additionally, WsART will be capable of displaying different data products on the same display such as displaying levels data on the same plot as raw data.

WsART will be required to decode and plot the WMO coded message. WsART will be required to generate a Skew-T plot from these data as well as from the PDS and the raw data. Additionally, WsART will be required to offer the following variables for plots:

- Pressure
- Temperature
- Relative Humidity
- Dew point
- Wind Speed
- Wind Direction
- Ascension Rate
- Latitude/Longitude
- Time
- Height

5.4.2 Tabular Displays

WsART will be required to generate and display tabular data displays. These displays will contain the data values acquired and generated by WsART. There will be a few standard tabular displays available in WsART.

- MET1 - same as the table provided by the MicroArt MET command.
- MET2 - processed data with Q values, time, height, angular and winds data as well.
- WANG - Wind and Angular data just like the MicroART WANG table.

In addition to these displays, WsART will allow the observer to create three customized tabular displays of the data by selecting series of fields and reporting frequency for the data. These custom configurations will be created by a report generator provided by WsART and can be printed and/or saved.

5.4.3 User Defined Data Set

WsART will be required to generate a user defined data set as part of any sounding or observation. The data set will be a combination of both the meteorological data and the winds data acquired during the observation and is generated for display only. This data set cannot be edited by the observer and is not stored in the local database. The observer will determine the time resolution and parameters displayed in the virtual data set. The data set can be displayed to the workstation display and/or saved to a disk file.

5.4.4 Hardcopy Generation

WsART will be required to provided the ability to generate a hardcopy of any graphic window or tabular display. The hardcopy will be in the form of a printout most likely from a laser printer connected to the workstation. Additionally, WsART will allow any screen or display in WsART to be printed via a print screen command.

5.4.5 Disk File Generation

All graphical data displays and/or tabular data displays including the user defined data set will be able to be stored in disk-based files by WsART.

5.5 Data Analysis Tools

Certain data analysis tools will eventually be incorporated into WsART. These additional tools will be added on an item per item basis and none are scheduled for WsART. Please refer to the subsequent builds sections for a list of the data analysis tools.

5.6 Recomputing During the Observation

From time to time it may be necessary for the observer to recompute or rework the observation because a critical station or prerelease data entry was incorrect and it was not discovered until the observation began. WsART will be required to allow the operator to modify the station or prerelease data during the observation. Changing these values will require that WsART automatically recompute or rework the meteorological values for the observation.

5.7 Successful/Unsuccessful Observation

WsART, as part of any observation, will be required to determine if the sounding was successful or unsuccessful. In either case, the operator must be notified of the success or failure of the sounding. When a successful or unsuccessful observation is identified, WsART will raise a dialog window containing a message indicating the success or failure. If an unsuccessful observation is identified, the reason for termination shall be identified and the flight terminated immediately.

A successful observation is identified if the following criteria are met:

- The balloon reaches 400 hPa before termination.
- The amount of missing data up to 400 hPa does not exceed thresholds specified under excessive missing data. (See Section 3.2.10 Excessive Missing Data.)

5.8 Identification of Flight Events/Anomalies

WsART will be required to identify certain flight events and anomalies. When these events/anomalies are identified, WsART will notify the operator by audio alert and by displaying the event or anomaly identified in a dialog window. See Section 3.2 for a complete description of all flight events/anomalies identified by WsART. It is important to note that certain critical events in an observation will require confirmation before continuing.

5.9 RADAT Message Generation

WsART will be required to calculate and construct the RADAT message as part of an observation. The RADAT message contains information about freezing levels in the observation. WsART will provide for construction of the RADAT message interactively when the freezing level is reached and observer selects the RADAT command, or automatically when the observation reaches the 400 hPa level.

The RADAT message is formatted by selecting freezing levels from the 0°C crossings. For each freezing level, the altitude is computed as well. WsART will be required to display the RADAT message after it is constructed on the workstation screen.

If the RADAT command is selected before the flight reaches the 400 hPa level and the freezing level has not been reached, WsART will not generate the RADAT message. Instead it will display a message indicating that the RADAT cannot be generated until the flight reaches the 400 hPa level.

If the temperatures are missing at all freezing levels, WsART will not generate a RADAT message but rather it will display a message indicating that the temperatures were missing and that RADAT messages cannot be constructed from interpolated data.

5.10 Coded Message Processing at 70 hPa

One of the requirements of a sounding system is that the coded messages be transmitted when the observation reaches the 100 hPa level. This is not always possible because the data needed to determine the pressure and the winds may not be available until sometime after the 100 hPa level has been reached. To ensure that all data are available, WsART will not begin processing of the coded message until the observation reaches the 70 hPa level. The level at which WsART will begin coded message generation (70 hPa) will be a operator selectable configuration item.

The coded message may be generated in one of two ways. Either automatically by the WsART software when the flight reaches the 70 hPa level (operator selectable), or interactively via operator selection of the code command option.

When the coded message generation is selected, WsART will create and display all parts of the coded message for operator review and modifications. Once all parts have been reviewed, the operator may transmit the coded message by selecting the transmit option in the coded message window. When the transmit button is selected, the coded message will be transmitted to the AWIPS network.

5.11 Level Selection

Levels selection is an integral part of all soundings. Levels are selected at points during the radiosonde ascent which enable an accurate profile to be defined of the pressure, temperature, humidity, and winds aloft at a specific location and time.

A level is a undulating surface in the atmosphere which intersects the temperature and RH profiles at a specific pressure/height and time. Selecting levels is necessary to reduce the amount of data required without significantly impacting the accuracy of representing the temperature and RH or wind profiles. Levels are selected when the flight either reaches a pre-determined specific pressure level or point in the observation (such as 70 hPa or at termination), or when a defined significant discontinuity occurs in the temperature or humidity lapse rates. Levels are selected for the purpose of minimizing the amount of data required for a coded message and to minimize message traffic.

5.11.1 Level Selection - Thermodynamic Variables

Levels will be selected from points in the time-tagged Local Processed Data file. These data points will provide a representative profile of the temperature, and relative humidity (RH) as a function of pressure or altitude. Levels will be selected either when the flight reaches a predetermined specific pressure level or when a defined, significant discontinuity occurs in the temperature and RH profiles. The criteria for selecting the levels is described in the sections below.

Criteria for level selection will be determined by examining the time-tagged Local Processed Data values for time, pressure, temperature, and relative humidity. Calculated data values for geopotential height, dew point, and dew point depression will be determined for each level selected. The height of the surface level in geopotential meters is set to that for the release point of the radiosonde. Temperature and relative humidity values will be interpolated for periods of missing data of less than one minute. Special procedures will be applied to strata with missing relative humidity or temperature data and cases of abnormal balloon ascension. Section 10. provides formulas and information on geopotential height, geometric altitude, and dew point computations.

Levels pertaining to temperature and humidity information will be classified into three types:

standard, mandatory significant, and additional levels. For each type, levels will be determined by the variables. Mandatory levels will be selected first, followed by significant levels.

5.11.1.1 Standard Pressure Levels.

Standard levels (i.e., standard isobaric surfaces) will be selected at the specified pressure levels shown in Table 5-1. Standard levels will be reported in Part A and Part C of the coded message (refer to FMH 3 - Appendix E for RAWINSONDE Observations).

Table 5-1: Standard Pressure levels

Surface	250	20
1000	200	10
925	150	7
850	100	5
700	70	3
500	50	2
400	50	1
300	30	

Standard pressure levels will be selected from the high data-rate time-tagged points closest to specified standard pressures. Data will be interpolated if a time-tagged point does not have a pressure exactly equal to the mandatory pressure level.

5.11.1.2 Mandatory Significant Levels

Independent of the standard isobaric levels selection, the reported significant levels alone shall make it possible to reconstruct the air temperature and humidity profiles within the accuracy limits of the criteria specified below. Only the pressure, temperature, and dew-point depression shall be reported at significant levels. Significant levels are categorized as mandatory or additional. The mandatory significant levels are selected first and then the additional significant levels.

5.11.1.2.1 Mandatory Significant Levels Selection

The following mandatory significant levels will be selected in the order and priority as listed below.

5.11.1.2.1.1 Surface Level

A level will be selected at the surface. The data will be obtained from surface instrumentation located near the release point. The surface pressure, temperature, dew-point depression, and wind direction and speed are reported, the surface geopotential height will not be reported in the messages.

5.11.1.2.1.2 Termination Level

The termination level will be selected at the highest usable point (in time) of ascent. In some cases, the termination level will be below 400 hPa and will require another release. Listed below are the types of terminations permissible and the point where the termination is to occur:

- Balloon Burst. When detected, the termination level will be placed at the last identifiable pressure point.
- Pressure Sensor Failure. When the pressure sensor fails the flight will be terminated at the last pressure measurement before the failure. Pressure sensor failures are usually related to a loss of signal or sensor dropouts causing a number of sampling points to be missing. Since the type of pressure sensor failure is dependent on the type of sensor used, requirements for this type of failure will be determined by the vendor.
- Excessive Missing or Rejected Data. When the flight terminates for excessive missing data (see Section 3.2.10 for definition), the termination level will be placed at the last pressure point where the data were considered valid.
- Weak Signals. When the flight is terminated due to weak signals, the termination level will be placed at the last pressure point before the first weak signals were detected. (This requirement will only be implemented if the information is available from the Met Decoder or RDF)
- Floating Balloon. When a floating balloon has been detected, the termination level will be placed at the last pressure point before the balloon began floating.
- Descending Balloon. When the balloon descends because of icing or turbulence to within 20 hPa of the surface of the ground, the flight will be terminated and the termination level will be placed at the highest point of the observation.
- Leaking Pressure Cell. Whenever a leaking pressure cell is encountered at pressures less than 400 hPa and the exact point where the leaking cell began cannot be identified, the observation will be terminated at 400 hPa.

WsART will include in the 101AdfAdf groups missing and doubtful data as well as corrected data.

5.11.1.2.1.3 Descending and Reascending Levels

A descending level will be selected when the balloon descends. A reascending level will be selected when the balloon reascends past the point of highest previous ascent. There are three cases where there will not be a reascending level following a descending level:

- If the balloon descends but never reascends past the highest ascent, there will be no reascending level. In this case, the descending level will be converted to a termination level after the flight terminates.
- If the data become missing after the balloon descends and do not reappear until the balloon is past the prior highest ascent, a reascending level cannot be selected as the data were missing where the balloon ascended past the prior highest point. Instead, an end missing data level will be selected where the data reappeared.
- If the reascending level coincides with a standard pressure, the standard level will be selected instead because standard levels have higher priority.

5.11.1.2.1.4 Missing Temperature

Begin and end missing temperature levels will be selected when temperatures are missing for more than one minute. If all data are missing at the point selected for the level, the level will be classified as a missing data level rather than a missing temperature level. In some instances, inability to acquire the radiosonde telemetry immediately after release results in missing data near the surface. If this occurs, the surface temperature in the data file will serve as the base of valid data for the interpolation procedure.

There are three cases where there will not be an end missing temperature level:

- If the data become missing and never return, there will be no end missing temperature level. The begin missing temperature level will be converted to a termination level when the flight is terminated after exceeding the excessive missing data limit defined in Section 3.2.10.
- If the balloon descends after the data become missing and does not reascend until after the data return, an end missing temperature level will not be selected as the balloon was not past the highest ascent when the data returned. Instead, a reascending level will be selected where the balloon passed the highest ascent.
- If the end missing temperature level is the same point as a mandatory level, the mandatory level will be selected because mandatory levels have higher priority.

If the flight has terminated, before the return of temperature data the last level selected will become the termination level.

5.11.1.2.1.5 Missing Relative Humidity (RH) Levels

Begin and end missing RH levels will be selected when RH is missing for more than 1 minute. Missing RH levels differ from missing temperature data levels in that the data for other variables between the begin missing RH level and the end missing RH level will still be checked against level criteria.

Geopotential height calculations require pressure, temperature, and optionally RH for each incremental level. If RH is missing, the calculation is based strictly on pressure and temperature.

5.11.1.2.1.6 Station Base Pressure Level

A level will be selected at the station base pressure used for computation of the stability index (see Section 10.1.10). The station base level (the pressure at the release location of the sounding) will be determined in accordance with the criteria given in Table 5-2.

Table 5-2: Stability Index Station Base Levels

Station Elevation	Station Base Pressure Level
Less than 100 m′	850 hPa
000 to 1400 m′	850 hPa

Table 5-2: Stability Index Station Base Levels

Station Elevation	Station Base Pressure Level
1401 to 2500 m′	850 hPa

The base pressure level will be selected from the Local Processed Data file at a point closest to the release location pressure.

5.11.1.2.1.7 Freezing Levels for the RADAT Message

Freezing levels will be selected below the 400 hPa level where the temperature is 0°C. Geopotential heights and RH values will be associated with these freezing/melting levels. A count of the number of freezing levels will be kept. Up to three freezing levels will be selected and reported in the RADAT message. They are as follows:

- The one nearest the surface.
- The one nearest the 400 hPa level.
- The intermediate one with the highest RH between the above two.

The heights associated with these RADAT message levels will be the standard atmospheric height based on the pressure associated with them (rounded to the nearest 100 feet). Appendix E, FMH-3, describes the coded message formats and Appendix D describes the formula for computing standard atmospheric heights.

5.11.1.2.1.8 Coincident Levels

If pressures at two selected levels are rounded to the same value, then the second level will be changed as follows:

- 1070.0 through 100.0 hPa - lower by 1.0 hPa
- 99.9 through 10.0 hPa - lower by 0.5 hPa
- 9.9 hPa through termination - lower by 0.1 hPa

5.11.1.2.1.9 Thick Inversions and Isothermal Layers

Mandatory significant levels will be selected at the bases and tops of temperature inversions, isothermal layers, or relative humidity inversions. Data between mandatory significant levels and between the surface level and the first mandatory significant level will be examined for inversions and isothermal layers. The decrease in pressure between the base and top of the inversion or isothermal layer will be at least 20 hPa in depth provided that the base of the layer occurs below the 300 hPa level or the first tropopause, whichever is higher. Bases and tops of inversion layers which are characterized by a change in temperature of at least 2.5 °C or a change in relative humidity of at least 20 percent, provided that the base of the layer occurs below the 300 hPa level or the first tropopause, whichever is the higher. An inversion layer may be comprised of several thinner layers separated by thin layers of temperature lapse. To allow for this situation, the tops of the inversion layers shall each be at a level such that no further inversion layers, whether thick or thin, shall occur for at least 20 hPa above the level. Such levels will be selected after all possible significant temperature and relative humidity levels between the two inversion levels have been selected. When a mandatory significant level with respect to air temperature and/or relative humidity and a standard isobaric surface coincide, data for that level shall be reported in Parts A and B or C and D as appropriate.

5.11.1.2.1.10 Mandatory Significant Superadiabatic Lapse Rates

If a temperature lapse rate between two consecutive levels exceeds 9.74°C per kilometer, the level with the greater time will not be selected if:

- The levels are less than or equal to 0.3 minutes apart
- The level with the greater time is a temperature or relative humidity level
- It is not within 20 hPa of the surface.

5.11.1.2.1.11 Levels between 110 and 100 hPa

If not previously selected as a mandatory significant or additional significant level, a level will be selected between 110 and 100 hPa.

5.11.1.2.1.12 Level within 20 hPa of Surface Level

A level will be selected within 20 hPa of the surface level if one has not already been selected for other reasons. The point of maximum temperature deviation from a straight line connecting the surface temperature and the temperature 20 hPa above the surface will be selected. The level will not be selected if temperature is missing.

5.11.1.2.2 Additional Significant Level Selection

The data between Standard and Mandatory Significant levels will be examined for additional significant levels. These levels will be selected at points where there is a significant departure from a piece-wise linear approximation of the vertical temperature or RH profile. The natural log of pressure is used as the vertical axis. The criteria for selection is based on a greatest departure from a linear interpolation of temperature of RH between two previously selected significant levels.

Temperature levels will be selected first, and significant relative humidity levels selected when no additional temperature levels can be identified.

5.11.1.2.2.1 Selection Criteria

Temperature and relative humidity levels will be selected at points of greatest departure from linearity (GDL). Departure from linearity is the absolute value of the difference between the measured temperature or RH at each time-tagged point and the temperature or RH at that point computed by linear interpolation, based on the logarithm of pressure, between the two nearest previously-selected levels on either side of the point. The point having the greatest absolute difference will be selected as the point of GDL between the two levels. If two points have the same difference, the first point in time is selected. A level will then selected at the point of GDL if the data at that point meet certain criteria (see Section 5.11.1.2.2.1.1 and Section 5.11.1.2.2.1.2 below). The procedure will then be repeated using the first point and the greatest departure point, then the greatest departure point and the second point, until no additional significant levels can be selected.

5.11.1.2.2.1.1 WMO Coded Message

For the WMO Coded Message, a temperature level shall be selected if the GDL exceeds ± 1.0°C for pressures from surface to the first significant level reported above the 300 hPa level or the first tropopause, whichever level is the lower, or by more than ± 2.0°C thereafter.

A relative humidity level will be selected if the GDL exceeds ± 10% for all pressures. WMO has the following levels which are necessary to ensure that the relative humidity obtained by linear interpolation between adjacent levels shall not depart by more than 15 percent from the observed values; (The criterion of 15 percent refers to an amount of relative humidity and not to the percentage of the observed value, e.g. if an observed value is 50 percent, the interpolated value shall lie between 35 percent and 65 percent.)

Levels which are necessary to limit error on diagrams other than T-log P shall be such that the pressure at one significant level divided by the pressure of the preceding significant level shall exceed 0.6 for levels up to the first tropopause and shall be determined by use of the method for selecting additional levels but with application of tighter criteria.

When a significant level with respect to air temperature and/or relative humidity and a standard isobaric surface coincide, data for that level shall be reported in Parts A and B or C and D as appropriate.

In Parts B and D, a layer for which data are missing shall be indicated by reporting the boundary level of the layer and a level of solid (/////) to indicate the layer of missing data, provided that the layer is at least 20 hPa thick. The boundary levels are the levels closest to the bottom and the top of the layer for which the observed data are available. The boundary levels are not required to meet “significant level” criteria. The boundary levels and the missing data level groups will be identified by the appropriate level numbers.

5.11.1.2.2.1.2 Levels Selection for National Climatic Data Center (NCDC) Archive

For the NCDC archive file, a temperature level will be selected if the GDL exceeds ± .5°C for pressures from surface to 100 hPa and ± 1.0°C from 100 hPa to termination.

A relative humidity level will be selected if the GDL exceeds ± 5% for all pressures.

5.11.2 Level Selection - Winds Aloft

After the thermodynamic level selection process is complete, wind levels will be determined. Wind directions for significant levels will be reported with respect to true north to the nearest five degrees of the 360 degree compass and one meter per second for speed. However, the processing and calculation of the winds and their use in the level selection will be recorded at the highest resolution obtainable with the windfinding equipment.

The signal processing and creation of the time-tagged wind vector file will be generated using the UCAR windfinding technique. The procedures in this Section are given in terms of a nominal one-minute file structure.

Four terms are used for defining the levels of winds aloft:

- Standard Pressure Surfaces
- Fixed Regional Levels
- Fixed National Levels
- Significant Levels

5.11.2.1 Standard Pressure Surfaces

Wind speed and direction will be reported for the standard pressure levels shown in Table 5-1 (Standard Isobaric Surfaces) and Table 5-3 (Fixed Regional and/or Significant Levels).

5.11.2.2 Fixed Regional Levels, National Levels, and/or Significant Levels

The wind profile is first analyzed to select mandatory significant levels. Maximum wind levels will be chosen from the list of selected significant levels. Fixed regional winds will then be computed and checked for coincidence (within 500 feet) with the significant levels selected. If significant levels coincide with the fixed regional levels (Table 5-3), the significant level takes priority and is reported in Parts C and D of the message. The data groups for the fixed and significant levels within the sounding will appear in ascending order with respect to geopotential altitude (MSL). see Table 5-3.

Table 5-3: Altitudes(MSL) of the Fixed WMO Region IV Wind Levels

Feet (Thousands)	Meters
1	300
2	600
3	900
4	1,200
6	1,800
7	2,100
8	2,400
9	2,700
12	3,600
14	4,200
16	4,800
20	6,000
25	7,500
30	9,000

Table 5-3: Altitudes(MSL) of the Fixed WMO Region IV Wind Levels

Feet (Thousands)	Meters
35	10,500
50	15,000
70	21,000
90	27,000
100	30,000
110	33,000
140	42,000
*	**

* Every 10,000 Feet upward ** Every 3,000 Meters upward

5.11.2.3 Significant Wind Levels

The reported significant level data alone shall make it possible to reconstruct the wind profile with sufficient accuracy for practical use. Care should be taken that:

- The direction and speed curves (function of the log of pressure or altitude) can be reproduced with their prominent characteristics.
- These curves can be reproduced with an accuracy of at least 10^o for direction and 10 knots for speed.
- The number of mandatory significant levels is kept strictly to a necessary minimum.

The reported mandatory significant wind data alone will make it possible to reconstruct the wind profile with sufficient accuracy for practical use. Care shall be taken that:

- The surface level and the highest level attained by the sounding constitute the first and the last significant levels. The deviation from the linearly interpolated values between these two levels is then considered. If no direction deviates by more than 10^o and no speed by more than 5 meters per second, no other significant level needs to be reported. Whenever one parameter deviates by more than the limit specified in (B) above, the level of greatest deviation becomes a supplementary significant level for both parameters.
- The additional significant levels so introduced divide the sounding into two layers. In each separate layer, the deviation from the linearly interpolated values between the base and the top are then considered. The process used in the previous bullet item is repeated and yields other significant levels. These additional levels in turn modify the layer distribution, and the method is applied again until any level is approximated to the above mentioned specified values. For the purpose of computational work, it should be noted that the values derived from a PILOT report present different resolutions:

1)Winds at significant levels are reported to the resolution of 5^{o} in direction and one meter per second in speed;

2)Any interpolated wind at a level between two significant levels is implicitly reported to the resolution of $\pm$ 10° in direction and $\pm$5 meters per second in speed.

5.11.2.4 Additional Significant Wind Levels

Other factors will be pertinent to the selection of significant level wind:

- The surface level and the highest level of the wind sounding will be specified as significant levels and they will be recorded as the first and last significant levels.
- The highest level of the sounding is defined as the highest 1000 foot level for which observed data are available. For example, if the ascent ended at 94,900 feet, the 94,000 foot level is the highest level of the sounding because it is the highest 1000 foot level for which observed data are available.
- When two significant wind levels occur within the stratum from 500 feet below to 499 feet above a reportable altitude, the significant wind having the faster speed will be recorded for that altitude. In the event that both the significant winds have the same speed, data for the one having the greater altitude will be recorded. For example, if the two significant winds occurred within the 26,500 - 27,499 foot stratum, the altitude to be recorded would be the 27,000 foot level.
- When a significant wind level occurs within the stratum from 500 feet below to 499 feet above a fixed Regional level, the speed and direction of the significant level wind will be recorded for that fixed Regional level in lieu of the data observed at the fixed level. An exception to this rule is when this occurs just above the surface. In this case, the surface wind will be the only one reported.
- When a significant level coincides with some other compulsory reporting level (standard isobaric, maximum wind, tropopause, etc.) the wind will be recorded as a significant wind level. In addition, the wind data will be recorded for the compulsory reporting level.

5.11.2.5 Terminating Wind

The highest level attained by the sounding shall be transmitted, provided:

- It is determined by consideration of the list of significant levels for wind speed, as obtained by means of relevant recommended or equivalent national method not by consideration of the original wind-speed curve;
- Shall be located above the 500 hPa surface and shall correspond to a speed of more than 30 meters per second;
- It constitutes the level of the greatest speed of the whole sounding.
- The time range for the message part must include the terminating level.

5.11.2.6 Maximum Winds

Maximum winds will be determined for Part A and/or Part C of the coded message.

Each maximum wind must satisfy all of the following criteria:

- The wind speed must be greater than 60 knots.

- It must occur above 500 hPa.
- A maximum wind level must be bounded by levels with winds of lower speeds than the maximum.

The following conditions disqualify a wind from being a maximum wind:

- A wind adjacent to a missing wind.
- A wind for a level whose pressure is equal to or less than 100 hPa (the dividing point for message Parts) if the adjacent wind at a level whose pressure is higher than 100 hPa, is greater.
- A wind for a level whose pressure is lower than 100 hPa if the adjacent wind below 100 hPa is greater.

Exception: The terminating wind qualifies as a level of maximum wind if it is the greatest wind speed of the entire flight. It must be the greatest wind speed in the range covered by a coded message Part (i.e., surface to 100 hPa or above 100 hPa).

5.11.2.6.1 Primary and Secondary Maximum Winds

Whenever more than one maximum wind level exists, these levels shall be reported as follows:

- The level of the greatest maximum wind speed shall be transmitted first;
- The other levels shall be classified in descending order of speed and be transmitted only if their speed exceeds those of the two adjacent minimals by at least ten meters per second;
- The levels of maximum wind with the same speed shall be encoded successively, beginning with the lowest one;
- Furthermore, the highest level attained by the sounding shall be transmitted, provided it constitutes the level of greatest speed of the whole sounding and satisfies criteria in Section 5.11.2.5 above.

If two winds with identical wind speeds satisfy the criteria for a maximum wind, the wind at the higher altitude will be selected. The search for a secondary maximum does not start until a minimal wind is found. A minimal wind is identified when the previous trend is decreasing or missing and the current trend is increasing. When a minimal wind is identified, its speed is saved.

A maximum wind is identified when the previous trend is increasing and the current trend is decreasing. When a maximum is found, it will become a possible candidate for a secondary maximum wind if <u>all</u> of the following conditions are met:

- It falls within the time range under consideration.
- There has been no missing wind since the previous minimum wind.

If all of the preceding conditions are satisfied, the maximum will be a candidate secondary maximum.

Once a candidate secondary maximum wind is identified, it will be confirmed when a wind is found whose speed is more than 20 knots less, provided that there is no intervening missing wind and that no intervening speed trend is increasing.

The remaining winds will be evaluated even after a secondary maximum is confirmed in case there is another wind with a higher speed, or the same speed but a higher altitude, that qualifies as another secondary maximum.

5.11.2.7 Vertical Wind Shear

The wind shear for the layer 3000 ft above and 3000 ft below the maximum wind will be computed and included in Part A and Part C of the coded messages. Refer to the FMH-3, Appendix D, for additional information on determining and coding wind shear.

5.11.2.8 Mean Winds

The mean wind direction and speed from the surface to 5000 ft altitude and from 5000 ft to 10,000 ft will be computed. The mean wind speed is a weighted average of wind speeds with respect to altitude. Likewise mean wind direction is a weighted average of wind direction with respect to altitude. If the wind data are missing for 2500 ft altitude or more, then the mean wind will be missing. The formula for computing the mean wind is described in the FMH-3, Appendix E.

5.11.3 Level Selection - Tropopause Level(s)

A level will be selected at the tropopause. When more than one tropopause is observed, each shall be identified and reported. The information required for selecting the tropopause(s) requires both thermodynamic and wind data for aiding in the determination; the tropopause is best determined by examining all the level data selected. The expected conditions at the tropopause, in simple terms, are an abrupt change in temperature lapse rate and a maximum wind speed. There may be, however, more than one such occurrence. Details on the definition of the tropopause are contained in WMO - No. 100 - Guide to Climatological Practices.

5.11.3.1 The First Tropopause

The tropopause is defined in terms of temperature lapse rate change, pressure level, and thickness of strata as described below.

- At pressure from 500 hPa to or through 30 hPa (all three must occur):
  The first instance (i.e. pressure) where the temperature lapse rate becomes less than or equal to 2°C per kilometer.
  The average lapse rate from the tropopause point to any point at a higher height, within the next 2 km does not exceed 2°C.
  The radiosonde ascends to 2 km or more above the initial tropopause point.
- No tropopause is reported at pressure less than 30 hPa.
- At pressures greater than 500 hPa (and only if no tropopause is found in A above, the smallest pressure (greater than 500 hPa) where the temperature lapse rate becomes less than or equal to 2°C per kilometer.
- If the average lapse rate from the tropopause point to any height within the next 1 kilometer does not exceed 3°C, nor for any other 1 kilometer layer at pressures greater than 100 hPa.

The pressure, geopotential height, temperature, dew-point depression, and wind direction and speed will be reported at the tropopause level(s).

The results of the automated procedure for determining the tropopause will be displayed for the observer to check. The purpose of such a display is to allow the observer to examine the selected tropopause and ensure that it is correct.

5.11.3.2 Multiple Tropopause Levels

If more than one layer satisfies the criteria of Section 5.11.3.1, then an additional tropopause level may be selected and reported.

5.11.4 Specific Level Selection Requirements

- The level selection process used in WsART is defined in the draft FMH #3, FCM-H3-1997. All rules, procedures, code definitions, etc. specified in FMH #3 will be satisfied or exceeded by the WsART software.
- WsART software will store all selected levels in the local database.
- WsART software will provide the capability to graphically and to display tabular levels in the levels data base record during a sounding.
- WsART software will provide the capability to edit levels. Editing of levels is restricted to inserting new levels, and deleting existing levels. The data for a particular level cannot be modified.
- WsART software will provide the capability of overlaying the levels on other plots such as the pressure profile.

5.12 Calculated Parameters

WsART, as part of any observation, will be required to compute and display a series of additional parameters. These additional meteorological parameters are required along with the levels selected in order to generate the coded message.

WsART will compute the same set of calculated parameters computed by the Micro-ART system. The parameters calculated are:

- RADAT Message
- Height of the 850 hPa, 925 hPa, and 1000 hPa levels
- Stability Index
- Minimum and Maximum Pressure
- Minimum and Maximum Temperatures
- Minimum and Maximum Relative Humidity
- Average Ascension rate
  Sfc to 400 hPa
  400 hPa to termination
  Sfc to 100 hPa
  100 hPa to termination
  Entire Flight
- Tropopause pressure, altitude, temperature, and wind
  First

Second
Third

- Mean wind speed and direction sfc to 5k ft., and 5k ft. to 10k ft.
- Primary and secondary maximum wind
- Wind shear 3k ft. below and above
- Termination Altitude for RAOB purposes
- Termination Altitude for wind purposes
- Termination Time
- Termination Pressure
- Termination Reason for RAOB purposes
- Termination Reason for PIBAL (wind) purposes

5.12.1 Calculated Parameter Window

The calculated parameter window will contain all the above values. The values for this window will be computed and the window will be generated and when the operator selects the Calculated parameters option, or when the calculate parameters command from the keyboard.

5.13 Levels and Winds Checks

Before generating the coded messages, WsART will be required to check the levels selected for the observation, and the wind data for a series of events which may indicate errors in the level selection and/or questionable wind data. The following checks will be performed by WsART prior to coded message generation:

- Check for Superadiabatic Lapse Rates between levels.
- Check to ensure selection of all mandatory pressure levels to flight termination.
- Check against the previous flight for excessive height and temperature changes.
- Check for reasonable wind speeds and directions.

If any errors are found during these checks, WsART will generate and display in a dialog window, a message for the operator. The formulas used for determine the above conditions are described in Section 10.

5.14 Coded Messages

Coded messages are generated as part of an observation. Coded messages are generated twice during each observation. Once when the flight reaches the 70 hPa (configurable) pressure level, and then again at the termination level.

The coded message is composed of six separate parts: TTAA, TTBB, PPBB, TTCC, TTDD, and PPDD. Parts TTAA, TTBB, and PPBB are generated at the 70 hPa level (configurable) and contain information about the flight from the surface to 100 hPa. Parts TTCC, TTDD, and PPDD are coded at flight termination and contain information about the flight from above the 100 hPa level to termination.

WsART will be required to code, store and transmit the coded message at the appropriate times during an observation. For a detailed description of the contents of the coded message parts, please refer to the Federal Meteorological Handbook No. 3, FCM-H3-1997 for a description of the WMO coded message.

5.14.1 Specific Coded Message Requirements

- The WMO coded message will be generated (i.e. coded) and transmitted as defined in the draft FMH #3,FCM-H3-1997, and the Manual on Codes WMO #306. All rules, procedures, code definitions, etc. specified in FMH #3 will be satisfied by the WsART software.
- The WsART software will store the coded message in the local database. Coded messages from previous flights can be recalled by ascension number. Once recalled WsART will allow the coded message to be edited and retransmitted.
- The WsART software will not allow the recall of previous flights coded messages during a flight.
- WsART software will provide the capability to display graphically/tabular the current coded message record during a sounding.
- WsART software will provide the capability to edit the coded message. Coded message editing is limited to adding/deleting coded groups. If a coded message is edited, the original message is not saved. An entry however will be recorded in the flight status log.

5.15 Coded Message Transmission

The WMO coded message is used for the international exchange of meteorological information. WsART will be required to transmit the WMO coded message to the AWIPS network connection.

The WMO coded message being transmitted to the AWIPS network requires that an AWIPS product identifier be added to the message header. This identifier hence forth known as the AWIPS identifier (AI) is composed of 8-10 characters in the following format:

CCCCNNNxxx

where:

CCCC	-	is a four letter code of the originating office.
NNN	-	is a 3 character product category identical to the AFOS NNN.
xxx	-	is a 1-3 character product designator identical to the AFOS xxx.

5.16 RADAT Message Transmission

WsART will be required to transmit over the network, the RADAT generated message as part of an observation. The RADAT message will be transmitted electronically to the AWIPS network. The RADAT message will be transmitted either when the observation reaches the freezing level, the 400 hPa level has been reached, or after an observation has terminated and as specified in the draft FMH #3,FCM-H3-1997. All rules, and procedures regarding RADAT message transmission in FMH #3 will be satisfied by the WsART software.

5.17 Flight Termination

WsART will terminate an observation for the following reasons:

- As a nominal flight termination where the reason for termination is balloon burst, weak signal, excessive missing data or recommend reject, or radiosonde failure at pressure less than or equal to 400 hPa.
- As the result of an unsuccessful observation, generally at pressures greater than 400 hPa.
- At the preselected pressure level when the observation is a special observation.
- Through operator selection of the termination command. When the operator terminates a flight using the termination command, WsART will display a confirmation message asking if the flight is really to be terminated. If the operator answers affirmatively, the flight is terminated, and any additional processing of the flight will be the operators responsibility. If the operator answers “no” to the prompt for flight termination, the flight will continue.

The criteria for identifying balloon burst, weak signals, missing data, and radiosonde failure are found in Section 3.2.

5.18 Data Products

WsART will be required to generate four specific data products as part of all observations. These data products are:

- Processed Data Set (PDS)
- WMO Coded message
- Distributed Data Set (DDS)
- NCDC Archive

5.18.1 Processed Data Set (PDS)

The PDS will be the source of data used to generate the WMO coded messages, derive various indices used for operations, and for other applications requiring processed data. This data is derived by processing the high resolution data reported by the radiosonde during its ascent. The processing performed by WsART to construct the PDS includes applying corrections to the pressure and temperature, and apply observer corrections and smoothing techniques.

The PDS is for NWS usage only and will not necessarily be archived at NCDC. The local processed data set will consist of the following:

- Corrected Temperature
- Corrected Pressure
- Relative Humidity
- Dewpoint
- Wind Speed
- Wind Direction
- U,V winds
- Height
- Latitude
- Longitude

5.18.2 WMO Coded Message

WMO coded messages are used for the international exchange of meteorological information including rawinsonde and pilot observations. Refer to Section 5.14 for a complete description of the WMO coded message.

5.18.3 Distributed Data Set (DDS)

The DDS created by WsART is a completely new product. This product will contain the High Resolution data such as the raw and corrected data as reported by the radiosonde, the processed data, levels data, WMO message, and pre-flight data.

Any data flagged as missing, questionable or reject will not be deleted by the operator or WsART, but will be saved in the DDS as it is reported. The DDS will not contain interpolated or extrapolated data substituted for missing data. Rather, the end users will decide which flags points, if any, to delete, edited, or interpolate to meet their application needs.

5.18.4 NCDC Archive

The NCDC archive will contain all data to be transmitted to NCDC. This archive will contain the DDS, certain station related information, and all data currently supplied by Micro-ART. This archive can be transmitted to NCDC electronically or stored to tape for local archiving or mailing.

5.18.5 Specific Data Product Requirements

- WsART will be required to generate the coded message automatically during and an observation. Once when the flight reaches the 70hPa level (configurable), and then at flight termination.
- WsART must provided the ability to generate the coded message interactively by the operator.
- WsART software will be required to store the WMO coded message in the local database.
- WsART software will be required to code and transmit the WMO coded message to fulfill the requirements currently satisfied by the Micro-ART system.
- WsART will be required to make the WMO coded message available to all data users linked to AWIPS, both directly and indirectly or via a gateway.
- WsART will be required to construct the DDS from the raw and corrected data sets acquired during an observation.
- WsART will be required to store the DDS in the local database.
- WsART will be required to transmit the DDS twice during each flight. The preliminary data product will be transmitted once the flight reaches the 70hPa level, and the second transmission will occur after termination and will contain all information acquired from 100 hPa to termination.

5.19 Additional Releases

Sometimes observations fail and it is necessary (desirable) to start a new observation. WsART will be capable of providing additional releases should an observation fail. WsART will be required to provide up to 3 releases for each ascension.

5.19.1 Ascension Number Management

Ascension and release numbers are entered as part of the pre-release information. WsART will be required to manage the ascension and release numbers for all observations. Special care must be taken when multiple releases occur for a single ascension. WsART will be required to control the generation of release numbers related to an ascension. WsART will be required to ensure that the correct release number is assigned and that no more than three releases occur for any ascension. If an error occurs such as more than three releases are attempted for an ascension, WsART will produce a warning message indicating the error.

5.20 Observation (Ascension / Release) Identification and Summary Data

All information relating to ascensions and releases will be stored in the ascension table including identification and summary data. Each release will have its own entry. This entry will contain information specific to that release such as the ascension, release number and date and time of the observation. Section 2.3.1.1.15 contains a complete description of the contents of an ascension table entry.

6. User Interface

This section describes the user interface requirements for WsART. Each section below describes the requirements in as much detail as possible.

Note that this section was written when the target development environment was a Hewlett Packard 9000/715 UNIX workstation and X-Windows/Motif . Since that time, the development platform has changed significantly. A Pentium based WindowsNT PC is now the target development environment. It is important to realize that there may be significant change in the overall look, feel, and operation of the user interface due to the platform change.

6.1 General

The WsART operator interface shall be implemented with a Graphical User Interface based on the X-Windows Motif system. One goal of the operator interface is to minimize the need for data entry. Within the operator interface, default entries will be supplied where appropriate to help minimize data entry.

The WsART user interface will be designed as a signal window application partitioned into several different sections each with a unique function. For example, the WsART user interface will cover the entire monitor but one section will be a dedicated status bar, one section a main WsART menu, and one a command line interface for keyboard input to name a few.

The requirements for the User Interface can be broadly divided into the following categories:

- Processing Operator Input
- Program Flow Control
- User Interface Components

6.2 Processing Operator Input

The WsART User Interface will allow the observer to enter commands both through keyboard entry of the command name and through selection of menu options using a “mouse” or pointing device. This dual method of command entry will allow the upper-air site to continue using the WsART software should the “mouse” or pointing device fail.

It is important to note that not all features of WsART will be available via keyboard input. Activities such as zooming graphics windows will not be available except though mouse or pointing device input. Even though all features will not be accessible, the core features required for a sounding will be always be available through keyboard entry.

6.3 Program Flow Control

Perhaps the most important feature of the User Interface will be to control the flow of the sounding application and its associated utilities. It is the responsibility of the User Interface to ensure that post-flight utilities and analysis options are disabled during an active sounding. It is also the responsibility of the User Interface to ensure that the pre-flight sequence occurs in the desired order.

Additionally, the User Interface will ensure that required values are entered before proceeding, and that the observer is notified of important events in a flight.

6.4 User Interface Components

The User Interface for WsART will be composed of the following components:

- Main WsART Window
- Administration and Off-line Utilities
- Pre-release
- Flight Observation
- Post Flight

6.4.1 Main WsART Window

All information displayed by WsART and all operator interaction with WsART will occur through the main window. The main window will be static for WsART and will be displayed when program execution begins, and will be dismissed when program execution terminates.

The main window is divided into six independent areas, each with its own function. The different pieces of the main window are as follows:

- WsART Status Window
- Warning/Error Window
- Main Menu Bar
- Option Menu Window
- Command Window
- Display Window

6.4.1.1 WsART Status Window

The WsART status window will be displayed at the top of the main window. This window will contain status information and be displayed as part of a normal sounding. During pre-flight prior to baseline, the following information will be displayed in the status window:

- Station Name
- Software Version Number
- Station Index
- Orientation Correction
- Station Elevation
- Date and Hour of the Last Flight
- Previous Ascension Number

During baseline and throughout the flight, the Status Window will display the following information:

- Station Name
- Time, Balloon direction, Pressure, Temperature, RH, Elevation angle, and Azimuth angle for the most recent data point.
- Launch Time

- Ascension Number

It is important to note that the PTU data will be displayed during baseline and updated continually throughout the flight.

6.4.1.2 Warning/Error Window

The Warning/error window will be displayed directly under the status bar. This window will display warnings generated during an observation such as the beginning and end of a strata of missing data as an example. Each time the system identifies an event or an anomaly, the message in addition to being stored in the flight log, is displayed in the warning/error window. The warning/error box will be scrollable and will be large enough to hold all warnings/errors generated in a sounding.

6.4.1.3 Main Menu Bar

The main menu bar resides directly below the warning/error window and directly above the display window. The main menu bar is composed of five push-buttons one for each function of the sounding system, and one to terminate WsART. The five options available in the main menu are:

- Sounding
- Monitor
- Analysis
- Utilities
- Exit

6.4.1.4 Option Menu Window

The option menu window is initially empty at WsART start-up. This window is used to display the many option menus available in WsART. Whenever the observer selects a button or enters a command which causes the display of a menu, this window will contain said menu. As an example, when the observer selects the sounding button from the main menu, the Sounding pre-flight sequence menu is displayed in the options menu window.

6.4.1.5 Command Window

The command window is displayed at the lower left corner of the main window directly beneath the option menu window. This window provides the keyboard interface to WsART. Through this window, the observer can enter text commands to execute WsART functionality.

6.4.1.6 Display Window

The Display window is kind of a generic data display window for WsART. This window is the largest window and is used by WsART to display the widest range of information. This window may contain one or many graphical or tabular displays of data. Data entry forms are displayed in this window as is the flight log.

6.5 Administration and Off-line Utilities

An important feature of the WsART system is the off-line utilities. A menu of off-line utilities will be displayed in the option menu window when the observer selects the utilities button from the main window. Utilities in WsART include the following:

- Radiotheodolite Orientation Check
- Equipment Check
- System, Site, and Plot Configuration
- Site Inventory Utility
- Report Generation
- Ascension Log Management
- NCDC Archive Management
- Local Database & Disk Management
- Calibration Data Management

Please refer to Section 7. of the requirements document for a description of the utility software for WsART.

6.6 Pre-release

Prior to balloon release, WsART will perform a series of pre-flight events. These pre-flight events are grouped into a common sub-menu and all events must occur prior to balloon release. The options in the pre-flight menu will be able to occur in a semi-random order. Semi-random in this sense means that the options cannot be skipped when going forward through the sequence. However, once a pre-flight event has occurred, the operator can choose to return to that option or any prior option(s) to re-enter/change fields.

6.6.1 Administrative Data Window

This is the first window displayed at the start of a new observation. The system will automatically provide entries for as many fields as possible. Initial entries may come from the previous observation.

This window contains administrative information relating to the flight such as:

- Time of the observation
- Observer Initials (3-characters)
- Ascension Number
- Release Number
- Special Observation

This window appears automatically at the start of a new observation and can be redisplayed at any time during or after the observation.

Unless otherwise noted below, the fields of this display may be displayed, entered, or edited at any time during the observation.

Some fields if selected will cause additional dialog boxes to be displayed. Such as the Special observation field and Flight Log. If a special observation is selected, a separate dialog box will be displayed prompting the observer for the termination level and the reason for the special observation.

6.6.2 Flight Equipment Data Window

The Flight equipment window contains information relating to the specific equipment used during the sounding. Information such as balloon type and size, and radiosonde type and serial number are specified in this window. This window is the second window raised during the pre-flight sequence. The flight equipment window will contain the following fields:

- Radiosonde Serial Number
- Radiosonde Type (Default read from Site Configuration)
- Balloon Manufacturer
- Balloon Type
- Balloon Date of Manufacture
- Balloon Size
- Train Regulator (Default value of ‘N’)
- Lighting Unit
- Ground Equipment Type (Data required for WMO 31313 code group)
- Surface Observation Equipment
- Parachute (Default value of ‘Y’)
- Nozzle Lift or Cubic Feet of Gas
- Payload Weight

Many values in this window will have default settings such as the radiosonde type, group equipment, surface observation equipment and parachute. Other fields such as Nozzle and payload will be calculated from entered values and known values and displayed.

Several additional fields may be displayed in the Flight Equipment window. They will be optionally displayed depending on the setting of configuration parameters.

- Launcher
- Balloon Gas
- Balloon Diameter

Certain fields in the window such as the radiosonde serial number must be entered before the sounding can continue.

6.6.3 Surface Data Window

This window displays the current readings from the observer entered values for the surface observations. This window allows for entry and editing of the official surface observation data.

The following basic information will be displayed in the surface observation window:

- Station Pressure in hPa
- Surface Temperature in °C
- * Surface Dewpoint in °C
- * Surface Wet Bulb Temperature in °C
- * Surface RH in percent

- Surface Wind Speed in Knots
- Surface Wind Direction in Degrees
- Clouds/WX - Now mandatory. The first 5 digits of the field must contain a 41414 group and will eventually be part of the coded message. Some optional fields will be displayed such as “temperature 12 hours ago”. This field is only active if the surface pressure value entered is less than 1000 hPa.

Note that the entries for RH, wet-bulb, and dewpoint are marked with an asterisk. Only one of these values will be entered for the surface observation. The other values will be computed from the entered value and the other surface observations.

All fields in the surface observation window must contain an entry. WsART will prompt the operator if entries are missing in the surface data window.

WsART will time tag the data entered in the surface data window. If the data has not been entered within 10 minutes of the balloon release, WsART will display a dialog box prompting the operator to verify/change the values in the surface observation window.

The surface observation window may be displayed at any time before, during, or after the observation and the values in the official surface observation can be edited at any time. If the surface observation is modified such as during a rework, WsART will recompute all the flight data with respect to the new surface observation and the observer may choose to retransmit the messages.

6.6.4 Verification of Prerelease Data - Administrative, Flight Equipment & Surface

Many fields in the pre-release data screens such as the surface observation values, and the radiosonde serial number are required before the observation can continue. Before a data window is dismissed, WsART checks all required values in the window to see that a value has been entered, and to ensure that the entered value is correct. Please refer to the data dictionary for WsART and Section 3. and Section 4. of this document for detailed information about the values and ranges in the pre-release data screens. If WsART detects missing or incorrect values (field size errors or data out of range), a dialog box is displayed notifying the observer of the error. The window is not dismissed, but remains active until the observer corrects the error or selects to cancel.

6.7 Baseline

The baseline phase of an observation involves verifying the operation of the radiosonde, determining the pressure offset, and verifying the operation of the radiosonde’s sensors. Radiosondes are precalibrated at the factory against known standards for each sensor. Nevertheless, they must be baselined (i.e., calibrated) for the specific observation, prior to their use. Radiosondes are also baselined for checking the electronics. The radiosonde pressure, temperature, and RH used during baseline will be derived from a 15 second running mean. WsART will display the running average and display the surface readings, the averaged readings, and the discrepancy for observer review. It is the responsibility of the observer to either reject or accept a radiosonde. The length of the running mean will be a configuration option.

6.7.1 Radiosonde Baseline Control Window

WsART will display the radiosonde baseline control window when valid data are received from the MET Decoder and the following fields will be displayed in the baseline control window:

Reference Station Pressure:	The operator must enter the surface pressure manually from a reference barometer at the radiosonde baseline point.
Radiosonde Pressure:	This field displays the average pressure reported by the radiosonde for the selected interval (15 seconds).
Reference Station Temp:	Operator Entered value. This represents the surface temperature entered for the station.
Radiosonde Temperature:	This field displays the average temperature reported by the radiosonde for the selected interval (15 seconds).
Reference Station RH:	Operator entered value. This field displays the surface RH as entered by the observer or as computed by WsART from other surface parameters.
Radiosonde RH:	This field displays the average RH reported by the radiosonde for the selected interval (15 seconds).
Pressure Discrepancy:	This field shows the difference between the reference surface pressure and the pressure reported by the radiosonde, computed as: radiosonde pressure minus reference pressure. The value is computed and updated automatically. This field can not be edited by the observer.
RH Discrepancy:	This field shows the difference between the reference surface RH and the average RH reported by the radiosonde, computed as: radiosonde RH minus average reference RH. The value is computed when the observer selects the compute averages button and can not be edited by the observer.
Temperature Discrepancy:	This field shows the difference between the reference surface temperature and the mean temperature reported by the radiosonde, computed as: radiosonde temperature minus mean reference temperature. The value is computed when the observer selects the compute averages button and can not be edited by the observer.

The radiosonde baseline window will the following action buttons:

Compute Mean	Calculates the mean of the data from the previous 15 seconds worth of points. These values are used to determine the discrepancies.
Accept Radiosonde	Activated when the baseline procedure is complete.

Reject Radiosonde Activated when the radiosonde is deemed unusable. The observer is prompted to acknowledge the operation. I.E. “Do you really want to reject the radiosonde ?”. If the answer is “yes”, the MET Decoder is reset and the administrative data window is displayed.

It is important to note that temperature and RH discrepancies may be way out of tolerance. These discrepancies should not blindly be used to reject a radiosonde. Rather the values reported by the radiosonde should be used as a sanity check to determine the correct operation of the temperature and RH sensors.

6.8 Flight Observation

WsART will be required to provide a series of status display windows for the observer. These status display windows provide information related to the status of the observation and the hardware components connected to the workstation.

The observation status display shows the current status of the observation and of radiosonde and wind data acquisition. This display shall be displayed always in the status window of the User Interface during the observation. The data displayed in this window are updated automatically by the software.

WsART will provide the following status display windows:

The following general information shall be displayed:

- Current date and time (UTC).
- Ascension Number.
- Release Number
- Elapsed time since release: Elapsed time displayed in minutes and hundredths of minutes or minutes and whole seconds. (Configuration item with a default of minutes and hundredths of seconds). This display should be blank prior to release.
- Radiosonde telemetry status: Search, Lock, Loss of Signal.
- Radiosonde Signal Strength (if available).

The following Radiosonde telemetry data shall be displayed:

- Corrected Pressure
- Temperature (corrected for solar radiation, if available; uncorrected temperature otherwise)
- Relative Humidity
- Auxiliary channel data, if available
- Telemetry downlink quality [0-100] when available.

The radiosonde altitude shall be displayed as:

- Current altitude of radiosonde
- Ascension rate - This value can be displayed in either meters/sec or meters/minute. This value is a configuration parameter and will default to meters/minute.

For ground-based RDF wind finding processor the following information will be displayed:

- Azimuth Angle.
- Elevation Angle.
- Position: latitude and longitude, or polar or rectangular coordinates with the station at the origin.

The Observation Status shall be displayed: (one of the following)

- Initializing
- Radiosonde calibration data has not been loaded
- Baseline
- Ready for Release
- Released
- Descending/Reascending
- Successful Release
- Successful Flight
- Terminated - *reason*.

7. Support Software Requirements

This section describes the general requirements for the support software associated with WsART. Each section describes one of the support software components utilized by WsART.

7.1 Station Data

One of the tables in the local database will contain information specific to the upper air site. The information contained in this table will not change very often. In fact most information will be set once and never changed. This information is generally not accessible by the observer because many entries contain information related to the station location. WsART will be required to provide support software for entering and changing the information in the station data table. Access to the information in this table will require password authorization since changing station specific information may lead to incorrect results from the workstation software.

7.1.1 Contents

The station data table will be maintained in the local database. It contains information specific to the upper-air site. Much of this information in the station data table is entered once when WsART is first configured and rarely, if ever changes. Section 2.3.1.1.1 describes the contents of the station data table.

7.1.2 Logging Updates

Since the majority of the information in the station data table will rarely change and since the information in the table has a direct effect on the operation of WsART, it is desirable that all changes to the station data table be logged.

A log of all changes made to the station data table will be maintained in the local database. This log will contain an audit trail of all modifications made to the station data table including the following information:

- The Date and Time of the change
- Who made the change
- A list of the parameters which changed and the new values.

7.2 System Configuration

The WsART software will be required to provide utility functions for determining and managing the system configurations. The configuration table will contain all system specific information for WsART such as the ports the peripherals are attached to, the administrators account name, the system serial number, etc. The utility routines will allow the system specific parameters to be modified through a series of menus. The utilities will limit access to the system configuration implementing password protection on the configuration table.

7.2.1 Logging Updates

Since the majority of the information in the system data table will rarely change and since the information in the table has a direct effect on the operation of WsART, it is desirable that all changes to the station data table be logged.

A log of all changes made to the system data table will be maintained in the local database. This log will contain an audit trail of all modifications made to the system data table including the following information:

- The Date and Time of the change
- Who made the change
- A list of the parameters which changed and the new values.

7.3 Ascension Log Management

From time to time it may be necessary to rebuild the ascension log or renumber a release due to operator error. WsART will provide a utility for regenerating the ascension log. Additionally, the serial numbers and calibration data for all radiosondes received during a month as well as the other inventory such as balloons, cylinders, train regulators, gas, hygristors, batteries, etc. received.

7.5.1 Calibration Data

Radiosonde calibration data are delivered with the radiosondes. The calibration data files are provided on diskette. Each radiosonde will have a corresponding calibration file. WsART will be required to provide support software for managing the storage and retrieval of the calibration data files. The data in the calibration file are critical to radiosonde initialization and testing and thus WsART will be required to manage the calibration data file inventory.

7.6 Resuming an Observation

Since a Uninterruptible Power Supply (UPS) will be used with WsART it is highly unlikely that a power failure will occur. Should a loss of power occur, WsART will have the capability of reprocessing the flight data up to and including the last good point of the flight.

7.7 Common Operating System Commands

Through WsART, the observer will have menu access to a series of Windows systems commands.

7.8 Training Aids / Tutorial

The purpose of the training aids and tutorials is to train the operator through an interactive process the different facets of WsART. It is meant to be one-on-one with the operator so that learning about the sounding system will be performed in a systematic fashion without the need for training personnel to visit the station.

No requirements for training aids/tutorials have been defined yet. It is important to note that some form of training aid/tutorial such as user documentation will be provided with WsART and the subsequent builds. This documentation will detail at a minimum how to use WsART and the subsequent releases to run an observation.

Also included with the training aids/tutorials will be a canned data set containing a good flight as well as some flight anomalies.

8. Reworking and Retransmitting Observations

From time to time, the observer may need to “rework” or “modify” the data in a flight for any number of reasons. WsART will be required to provide for reworking and transmitting any or all previous observations archived in the local RRS database. The rework operations provided by WsART will allow the observer to load, modify and save all data acquired during pre-release, and all data acquired and computed during an observation. Essentially the same operations are provided during a rework as are provided during a sounding except that the data are retrieved from an archive instead of being acquired from the radiosonde. WsART will be able to rework flights from a specified range of days prior to the current date. Initially this value will be set to 31, and will be a configuration parameter. Once the observation has been reworked, WsART will provide the observer with the option of transmitting the results of the rework.

9. Data Products and Data Archiving

WsART will create a series of data products and archives. These data products reflect the information in a flight and are disseminated for storage, analysis, and forecasting. Some of the products are sent to specific destinations such as the NCDC archive, some are maintained locally on the WsART PC, and others such as the WMO Coded Message are broadcast to the AWIPS network for all to use. The following archives and products are created by WsART:

- WMO Coded Message
- RADAT Message
- Local Data Archive
- NCEP Distributed Data Set (DDS)
- NCDC Archive

Some of the products created by WsART will optionally be storable on hard media for delivery via United States Postal Service (USPS) or other similar delivery service rather than electronic transmission. All electronic transmission of data products within WsART will occur through a modem connection. This is due to the fact that WsART is a stand-alone system with no direct connection to the AWIPS network.

9.1 WMO Coded Message

The WMO coded message which contains the coded flight information will be transmitted automatically to the AWIPS LAN twice during each flight. Once at 70 hPa (configurable), and then again at termination. The message transmitted at 70 hPa (configurable) will contain all information up to the 100 hPa level, while the message transmitted at termination will contain information for the entire flight. Additionally, the observer may generated the coded message any time during an observation by selecting the code option. The reason that automatic coding of the first message is not started until 70 hPa (configurable) is due to the fact that there is a certain lag to the data, and all data necessary to code the 100 hPa level may not be available until the 70 hPa level has been reached.

9.2 RADAT Message

The RADAT message contains all zero crossings or freezing levels in a flight. WsART will construct the RADAT message by selecting all zero crossing levels specified in the levels data table. The RADAT message is generated automatically and transmitted by WsART at the 400 hPa level. The observer can manually generate the RADAT message at any level above 400 hPa by manually selecting the radat option. Attempting to generate the RADAT message below 400 hPa will result in an error message. The RADAT message will be encoded as specified in Appendix E, Table 0421 of FMH 3, FCM-H3-1997.

9.3 Local Archive

WsART will create the local data archive from the data acquired during an observation. The data stored in this archive will be the requisite data necessary for “reworking” and will include information such as surface observation, raw and corrected PTU, and winds data. WsART will be able to either store the local data set on the PC hard drive or optionally on a tape.

9.4 NCEP Distributed Data Set (DDS)

WsART will create an entirely new data product format know as the Distributed Data Set (DDS). The data listed in Section 9.4.1 through Section 9.4.2.2 are contained in the DDS and transmitted in real-time. The first transmittal will occur once the radiosonde reaches the 70 hPa level and will contain all data up to the 100 hPa level. The DDS will again be transmitted once the flight terminates. The second transmission of the DDS will contain all data acquired from 100 hPa to termination.

WsART will provide the capability of transmitting the DDS to the AWIPS network. WsART will create, format, and send the DDS in the **B**inary **U**niversal **F**orm for the **R**epresentation of meteorological data format (BUFR).

9.4.1 Time stamped sonde pressure, temperature, and humidity (PTU) data

This is the raw data as reported by radiosonde. This data may represent an average of several values over a period sample (vendor specific) thus allowing for the removal of random and systematic instrument noise. This data is reported every 1 to 2 seconds of the flight (vendor specific).

Time Stamp:	Elapsed Time (Minutes & Hundredths of seconds)
Pressure:	0.01 hPa to 1070.00 hPa to the nearest 0.01 hPa
Uncorrected Temperature:	-100.0°C to +50.0°C to the nearest 0.1°C
Temp corrected for radiation errors:	-100.0°C to +50.0°C to the nearest 0.1°C
Humidity:	0.0% to 100.0% to the nearest 0.1%
Quality Indicators:	Generated by the radiosonde. (vendor specific)
The Updated Processed Data Quality Indicators:	Integer (Refer to Table B-1 for a complete listing of the Quality Indicators in WsART)

9.4.1.1 Time stamped U & V winds:

This data is the result of processing (converting the angular data and height to X,Y, Z, and then to U,V,lat, and lon) 6 second angular data supplied by RDF equipment. The wind data will be reported every 6-seconds

Time stamp:	Elapsed Time
6 second U:	Real (m/sec)
6 second V:	Real (m/sec)
6 second UV Quality Indicators:	Integer (Refer to Table B-1 for a complete listing of the WsART Q/C Flags)
Calculated latitude:	DDD:MM:SS
Calculated longitude:	DDD:MM:SS
Height:	meters
Flags:	Bit flags (Missing, Interpolated,...)

9.4.2 Administrative Data

The administrative data set listed in Section 9.4.2.1 will be included in the first transmittal of the DDS (when the radiosonde reaches 70hPa), but only the twelve data groups listed in Section

9.4.2.2 will be included in the second DDS transmittal (when the radiosonde flight terminates).

9.4.2.1 Administrative Data included with First Transmittal

Call Letters:	4 capital letter symbol
WMO#:	Integer representing block number/station identifier.
WBAN#:	5 digit number
Release point latitude:	0° 0" - 90° 0" N/S
Release point longitude:	0° 0" - 180° 0" E/W
Observer initials:	3 character string
Ascension number:	1 - 999
Date/release time:	mm/dd/yyyy, hh:mm:ss
Release point elevation:	Integer - (msl)
Barometer elevation:	Integer - (msl)
Radiosonde type/serial#:	Vaisala or VIZ and an integer
Radiosonde sensors used:	Character String
Radiosonde calibration data:	Data File containing calibration values ala MicroART
Operating radio frequency:	403MHz or 1680 MHZ
Ground sys./tracking type:	ART-RDF or GPS
Software version number:	XX.XX
Surface weather observation:	
Pressure:	hPa
Temperature:	° C
RH:	%
Wet-bulb Temp:	° C
Dewpoint Temp:	° C
Temp 12hrs ago:	° C
Clouds/WX:	$N_hC_lhC_mChWWWW$
Surface obs. equip. used:	Character string
Surface obs. equip.dist/elev from release point:	Integer (msl), Integer (m)
Balloon shelter type:	Character String (e.g., High bay or BILS)
Balloon manufacturer/type:	Character String
Balloon lot #:	Integer
Balloon manufacture date:	mm/dd/yyyy; Must be 1980 - present
Gas used:	Hydrogen or Helium
Gas amount (free lift (gm) or ft^3):	Integer (ft^3)
Flight train length:	Integer (m)
Train regulator (y/n):	Y or N
Light unit (y/n):	Y or N
Rooftop release (y/n):	Y or N
Observer:	Contract or NWS
Data corrections:	Character String - (e.g. radiation corrections applied)
Reason for Wind Processing Term:	(TBD)
Reason for flight term:	Character String (e.g., Burst, etc.)

9.4.2.2 Administrative Data included with Second Transmission

Call Letters:	4 capital letter symbol
WMO#:	Integer representing block number/station identifier.
WBAN#:	5 digit number
Release point latitude:	0° 0" - 90° 0" N/S
Release point longitude:	0° 0" - 180° 0" E/W
Observer initials:	3 character string
Ascension number:	1 - 999
Date/release time:	mm/dd/yyyy, hh:mm:ss
Release point elevation:	Integer - (msl)
Barometer elevation:	Integer - (msl)
Radiosonde type/serial#:	Vaisala or VIZ and an integer
Radiosonde sensors used:	Character String
Data corrections:	Character String - (e.g. radiation corrections applied)
Flight duration:	hh:mm:ss
Time of termination:	hh:mm:ss
Termination height & PTU:	height - (msl) pressure - hPa Temp - ° C RH -%
Reason for Wind Processing Term:	(TBD)
Reason for flight term:	Character String (e.g., Burst, etc.)

9.5 NCDC Archive

In addition to the current upper air data being archived at NCDC, the WsART will generate a new, more detailed, archive product. This enhanced product will contain all parameters found in the DDS (listed in Section 9.4) and those listed below in Section 9.5.1 through Section 9.5.5 . The WsART is being designed so this new NCDC archive can be sent electronically to NCDC, archived to hard media or both. The handling of the NCDC archive will be dependent on the WsART station configuration**.**

The exact transmission interval for the NCDC archive product is not currently defined.

9.5.1 Time stamped WsART processed PTU data:

Processed data is arrived at by applying smoothing, interpolation, outlier removal, data plausibility checks and Quality Indicators to the raw PTU data provided by the radiosonde. This data is reported at the same resolution as the raw PTU data, every 1 to 3 seconds of the flight.

Time stamp:	Elapsed Time
Processed Pressure:	0.01 hPa to 1070.00 hPa to the nearest 0.01 hPa
Processed Temperature:	-100.0° C to +50.0° C to the nearest 0.1° C
Processed Humidity:	0.0% to 100.0% to the nearest 0.1%
Processed Quality Indicators:	Standard deviation of a least squares fit
PTU flags:	Bit flags (Missing, Interpolated,...)
Calculated Geopotential Heights:	0m to 45,000 m to the nearest 1m
Calculated Dew Pt. Depression:	Real (° C)

9.5.2 Time stamped Radio Direction Finder (RDF) angular data:

This data is a “Snapshot” of the angular data acquired from the MCU printer port. The data is reported at 6 second intervals.

Time Stamp:	Elapsed Time (Frame Counter)
Azimuth:	0.00° to 360.00° to the nearest 0.01°
Elevation:	-5.00° to +95.00° to the nearest 0.01°
Height:	Meters

9.5.3 Time stamped 1 minute U & V winds:

This data contains a one minute average of the six second processed wind data. (An average of ten 6 second values.)

Time Stamp:	Elapsed Time
1 minute U:	Real (m/sec)
1 minute V:	Real (m/sec)
1 minute UV Quality Indicators:	(TBD)
Height:	Meters

9.5.4 Time stamped Levels data:

This data represents the Mandatory, Significant, and Special winds and PTU levels selected from the Processed Data Set (Processed PTU and Processed Winds Data).

The following parameters will be included in the Mandatory PTU Levels, Significant PTU Levels and Special PTU Levels.

Temperature:	° C
Pressure:	hPa
RH:	%
Dewpoint:	° C
Dewpoint Depression:	° C
Geopotential Height:	Meters
Flags:	Bit Flags indicating Level Type

The following parameters will be included in the Mandatory Wind Levels, Significant Wind Levels and Special Wind Levels.

Height:	Feet(K)
Wind speed:	kts
Wind direction:	Degrees (to the nearest 5)
Flags:	Bit Flags indicating Level Type

9.5.5 WMO coded message:

This data represents the result of reducing and coding levels data into WMO format.

WMO coded message:	See FMH#3-1997

9.6 Specific Data Archiving Requirements

- WsART will provide for management of the local data archive through the local data base.
- WsART will be capable of retrieving from the local data base, a local data archive and “reworking” the sounding from the data.
- WsART will maintain the local archive data on the PC hard drive for specified number of days at which time, the data will be automatically deleted. The amount of time data is stored on the PC is a configuration item. The default time is 31 days.

10. Formula and Constants for Calculated Parameters

The WsART will use the radiosonde and ART information to calculate intermediate and final meteorological parameters needed to construct the WMO upper-air messages. The WsART will use the most accurate formulations that describe the physical relationship between variables in the most explicit manner. This will help in the code documentation, debugging, and software revisions.

10.1 Calculation of Atmospheric Thermodynamic Parameters

The primary calculated thermodynamic parameters of the atmosphere needed for message construction are the geopotential height and the dew-point temperature. Several intermediate parameters are necessary to compute the height and dew-point; they are virtual temperature, water vapor pressure, and the water vapor enhancement factor.

10.1.1 Adjustment of Sonde Pressure Sensor to Reference Surface Pressure

The WsART will adjust the radiosonde's pressure sensor measurements to that taken by a precision barometer during the radiosonde preparation and baseline check.

1) For radiosonde pressure measurement between 1070.0 hPa to 1.00 hPa, use the following equation to adjust the radiosonde pressure measurements to an accurate surface pressure measurement made at the time and place of launch.

$$P_c = P + \Delta P \cdot \left(\frac{\ln(P)}{\ln(P_0)}\right)$$

where:

P_c = corrected pressure

P = pressure reported by radiosonde

ΔP = initial pressure correction

(difference between radiosonde and station reference at baseline)

P_0 = uncorrected surface pressure reported by radiosonde

Since the natural log of 1 is 0, the pressure will not be corrected for radiosonde pressure measurements less than or equal to 1 hPa.

10.1.2 Calculation of Geopotential Height

The WsART will compute the geopotential height in standard geopotential meters for each data point reported by the radiosonde using the following procedure.

1) Use the finite-difference form of the integrated hydrostatic equation to determine the geopotential height of one data point above another data point (Hess, 1979).

$$Z_2 = Z_1 + \frac{R_d \cdot \overline{T_v}}{g_0} \cdot \ln\left(\frac{p_1}{p_2}\right)$$

where:

Z_2 = The geopotential height of the second data point above the first data point.

Z_1 = The geopotential height of the first data point (in standard geopotential meters).

R_d = The gas constant for dry air - R^* / m_d = 8314.32 / 28.963 = 287.04 $m^2\ s^{-2}\ K^{-1}$.

$\overline{T}_v$ = The mean virtual temperature of layer between data points.

g_0 = The standard acceleration of gravity 9.80665 $m\ s^{-2}$.

p_1 = The pressure of the first data point (in hPa).

p_2 = The pressure of the second data point.

2) The heights are accumulated from the surface. Starting from the station height, the geopotential height calculated from each radiosonde data point is added to the previous height.

The radiosonde’s pressure, temperature, and humidity data need to be conditioned so that noise does not contaminate the calculated heights.

10.1.3 Calculation of Mean Virtual Temperature

The virtual temperature is the temperature a parcel of dry air would have if it were at the same total pressure and density of the initial parcel of moist air. This is a construct that simplifies the gas law by adjusting the temperature rather than the gas constant for a mixture of dry air and water vapor.

The WsART will compute the virtual temperature for each data point reported by the radiosonde and the mean virtual temperature of the layer between adjacent data points using the following procedure.

1) Use the following equation to determine the virtual temperature of the data point (Petterssen,

1956).

$$T_v = \frac{T}{\left(p - \left(1 - \frac{m_v}{m_d}\right) \cdot e'_w\right)}$$

where:

T_v = Virtual temperature of the data point in K

T = Temperature of the data point (in Kelvin degrees).

p = Pressure of the data point (in millibars).

m_v = molecular weight of water (vapor) = 18.0152 (in g/mol).

m_d = apparent molecular weight of dry air = 28.963 (in g/mol)

- with CO2 mole fraction 0.00033.

e'_w= The enhanced actual vapor pressure of the moist air (in millibars).

2) Since the data rate is 6 seconds or less, the mean virtual temperature of the layer will be taken as the arithmetic mean of the virtual temperatures for the two data points.

$$\bar{T}_v = \frac{(T_{v1} + T_{v2})}{2}$$

10.1.4 Calculating the Enhanced Vapor Pressure

The WsART will compute the enhanced actual vapor pressure of moist air for each data point reported by the radiosonde using the following procedure.

1) Use the following equation to determine the enhanced actual vapor pressure of moist air of the data point (Buck, 1981).

$$e'_w = f_w \cdot e_w = f_w \cdot \frac{U}{100} \cdot e_{sw}$$

where:

e'_w = the actual enhanced water vapor pressure with respect to water of moist air for the data point, in hPa.

f_w = the enhancement factor; a correction for the departure of the air/water vapor mixture from ideal gas laws.

e_w = the actual vapor pressure with respect to water of moist air acting as an ideal gas.

U = the relative humidity of the moist air, in %.

e_{sw} = the saturation vapor pressure with respect to water of moist air acting as an ideal gas. It is the partial pressure of water vapor required for saturation at the actual air temperature.

10.1.4.1 Calculation of the Saturation Vapor Pressure

1) Use the following (Wexler) equation to determine the saturation water vapor pressure with respect to water and acting as an ideal gas (Buck, 1981).

$$e_{sw} = 0.01^{(A \cdot T^{-2} + B \cdot T^{-1} + C + D \cdot T + E \cdot T^2 + F \cdot T^3 + G \cdot T^4 + H \cdot \ln(T))}$$

where:

e_{sw} = the saturation vapor pressure with respect to water of moist air acting as an ideal gas.

T = Absolute Temperature (in Kelvin).

A = -2.991 27 2 9 x 10^3

B = -6.017 012 8 x 10^3

C = 1.887 643 854 x 10^1

D = -2.835 472 1 x10^{-2}

E = 1.783 830 1 x 10^{-5}

F = -8.415 041 7 x 10^{-10}

G = 4.441 254 3 x 10^{-13}

H = 2.858 487 x 10^0

10.1.4.2 Calculation of the Enhancement Factor

1) Use the following equation to determine the enhancement factor with respect to water (Buck, 1981).

$$f_w = 1 + A + p[B + C(T + D + Ep)^2]$$

where:

f_w = enhancement factor with respect to water

p = pressure in millibars

T = temperature in Celsius

A = 4.10×10^{-4}

D = 3.06×10^{1}

B = 3.48×10^{-6}

E = -3.80×10^{-2}

C = 7.40×10^{-10}

10.1.5 Calculation of Radiosonde Ascent Rates

The WsART will determine radiosonde ascent rates for all data points, for various layers and to various levels using the following formula

$$AscentRate = \frac{Z_2 - Z_1}{t_2 - t_1}$$

where:

Z_2 = geopotential height of data point 2

Z_1 = geopotential height of data point 1

t_1 = time stamp of data point 1

t_2 = time stamp of data point 2

Standard ascent rates are reported for surface to 400 hPa and from 400 to flight termination in meters per minute and meters per second. Other standard ascent rates will be surface to 100 hPa and surface to termination. The WsART will also be capable of determining ascent rate between any and all data points using utility that will accept user specified levels, layers, and smoothing routines.

10.1.6 Calculation of Dew Point Temperature

The WsART will compute the dew point temperature for each data point reported by the radiosonde using the following procedure.

1) Use temperature estimates with an iteration technique on the equations that calculate saturated enhanced water vapor until the estimate converges to within a certain tolerance of the known

actual enhanced water vapor pressure of the moist air.

2) Knowing that the dew point temperature is always less than the actual temperature, the first guess temperature would be -100°C. This would test if the dew point was at an extreme. The second guess would be one half of the difference. The next guesses would be one half of the difference in the direction where the iterated vapor pressure will converge to the actual vapor pressure.

3) The tolerance or the convergence test would be ±0.05°C.

10.1.7 Determining Superadiabatic lapse rates

WsART will be required to identify and flag superadiabatic lapse rates. The following formula will be used by WsART to determine if superadiabatic lapse rates should be flagged questionable or recommend reject.

$$L_R = \frac{T_3 - T_1}{Z_3 - Z_1}$$

where:

L_R	=	Lapse rate (°C/meter).
T_1	=	Temperature at level 1.
T_3	=	Temperature at level 3 (3 second later w/ 1 second reporting interval).
Z_1	=	Height (meters) at level 1.
Z_3	=	Height at level 3 (15 meters higher w/ 1 second reporting interval).

This check advances forward from level to level (i.e., T_1 to T_3, T_2 to T_4, T_3 to T_5, etc.).

10.1.8 Calculation of Potential Temperature

The WsART will compute the potential temperature for each data point reported by the radiosonde using the following procedure.

1) Use the following equation to determine the potential temperature of each data point (Garratt,

1992).

$$\Theta = T\left(\frac{P_0}{P}\right)^{\frac{R_d}{c_p}}$$

where:

Θ = Potential temperature in K

T = Actual temperature in K

P_0 = Pressure to which Θ is referenced, 1000 hPa

P = Actual pressure associated with T

R_d = Gas constant for dry air

c_p = Specific heat of dry air at constant pressure (Garratt, 1992)

$c_p = 1005 + (T\text{-}250)^2/3364 \cong 1005\text{J kg}^{-1}\text{ K}^{-1}$

10.1.9 Calculation of Standard Atmosphere Heights for RADAT Message

The WsART will compute a geopotential height for freezing levels. The geopotential height will be that of a standard atmosphere for the corresponding pressure where the 0°C crossing occurs. The following procedure will be used.

1) Find the pressure corresponding to a 0°C crossing point.

2) Use the following formula to determine the geopotential height of a pressure in a standard atmosphere (Iribarne, 1981).

$$Z_{std} = -\frac{T_0}{\gamma}\left[\left(\frac{P}{P_0}\right)^{\frac{R_d\gamma}{g_0}} - 1\right]$$

where:

Z_{std} = geopotential height of pressure in a standard atmosphere

T_0 = initial temperature of the standard atmosphere, 288.15 K

γ = temperature lapse rate of the standard atmosphere, 0.0065 K/sgpm

P = Pressure of interest

P_0 = initial temperature of the standard atmosphere, 1013.25 hPa

R_d = universal gas constant for dry air

g_0 = standard gravity acceleration constant, 9.80665 m/s^2

This equation is good for pressures greater than 226.32 hPa (the tropopause in the standard atmosphere - 11 kgpm)

10.1.10 Calculation of the Showalter Stability Index

The WsART will compute the Showalter Stability Index for the RAOB message.

1) Use the 850 hPa temperature and dew point temperature to determine the LCL. (use the base pressure for stations above 850 hPa).

2) From the LCL, raise the parcel up its saturated adiabat to get its 500 hPa temperature.

3) Subtract this temperature from the actual temperature at 500 hPa.

4) The value of the difference is the Showalter Index.

10.1.10.1 Calculating the LCL

The Lifted Condensation Level (LCL) is the level to which unsaturated air would have to be raised in a dry adiabatic expansion to produce condensation. At the LCL of the raised air parcel, the mixing ratio becomes equal to its initial saturation mixing ratio at the base pressure.

1) find the saturated mixing ratio for the initial conditions by using the mixing ratio formula and the saturated vapor pressure for the initial dew point temperature and initial base pressure (850 hPa) (Iribarne, 1981).

$$r = \frac{\varepsilon e'_T}{P - e'_T}$$

where:

r = mixing ratio (g/kg)

$\varepsilon = 621.97 = m_v/m_d \times 1000$ g/kg

e'_T = vapor pressure at temperature T

P = Pressure

2) Decrease the pressure by 1 hPa increments; use Poisson's equation to find the corresponding dry adiabatic temperature (Iribarne, 1981).

$$T_{new} = T_{base}\left(\frac{P_{new}}{P_{base}}\right)^{\chi_d}$$

where:

$\chi_d = R_d/C_p = 0.286$

3) Calculate new mixing ratio based on new temperature, pressure, and saturated vapor pressure.

4) Repeat steps 2 and 3 until the difference between the new mixing ratio and the initial saturated mixing ratio becomes zero. The pressure where this condition exists is the LCL.

If the station is above the 850 hPa pressure surface, the base pressure of the station can be substituted for the 850 hPa values.

10.1.10.2 Calculate the 500 hPa Temperature of the LCL's Saturated Adiabat

The saturated air parcel is raised adiabatically from the LCL to 500 mb, keeping all the water condensed during the process. Knowing the rate of temperature change with respect to pressure, the parcel is raised incrementally to the 500 hPa level.

1) find the rate of temperature change with respect to pressure using the following formula (Iribarne, 1981). Note that the rate changes with temperature and pressure.

$$\frac{dT}{dp} = \frac{\dfrac{R_d}{p-e_w} + \dfrac{\varepsilon l_v e_w}{T(p-e_w)^2}}{\dfrac{c_{p_d} + c_w r_{t,w}}{T} - \dfrac{l_v r_w}{T^2} + \dfrac{r_w}{T}\dfrac{dl_v}{dT} + \dfrac{de_w}{dT}\left[\dfrac{R_d}{p-e_w} = \dfrac{l_v(e+r_w)}{T(p-e_w)}\right]}$$

where:

T = Temperature (kelvin)

p = pressure (pascal)

R_d = Gas constant for dry air

e_w = saturation vapor pressure for temperature T

ε = md/mv @ 0.622

c_{pd} = specific heat of dry air @1005 J/kg K - (@ 0°C)

c_w = specific heat of water @ 4218 J/kg K - (@ 0°C)

c_{pv} = specific heat of water vapor @1805 J/kg K - (@ 0°C)

$r_{t,w} = r_{w,\ lcl}$; mixing ratio of total water content; $r_{tw}=r_w + m_w / m_d = r_w + r_{w,\ lcl} - r_w = r_{w,\ lcl}$

(m_w is total mass of water)

l_v = latent heat of vaporization for water @ 2.501 x 10^6 - (@ 0°C)

r_w = saturated mixing ratio for temperature T

$$\frac{dl_v}{dT} = c_{p_v} - c_w$$

$$\frac{de_w}{dT} = \frac{\varepsilon l_v e_w}{R_d T^2}$$

2) decrease pressure and determine temperature by applying the rate of temperature change for the change in pressure.

3) calculate a new rate of temperature change for the new temperature and pressure.

4) continue steps 2 and 3 until the parcel reaches 500 mb.

5) subtract this temperature from the actual 500 mb temperature of the sounding.

6) report the temperature difference as the Showalter Stability Index.

10.2 Calculation of Radiosonde Position and Upper-Level Winds

The WsART will use the existing Automatic Radio Theodolite ground equipment to track the radiosonde during an observation. The hosting of the operational radiosonde upper-air observation system software onto a more powerful computer created the opportunity to use more sophisticated wind-finding algorithms on all the available data. The following algorithms are a combination of earlier work done by NWS and NCAR.

10.2.1 The Wind-finding Process

- The wind-finding process consists of the following process:
- Convert the radiosonde's geopotential height to geometric height
- Calculate the earth's radius at the station latitude
- Calculate the central earth angle between the station and the radiosonde
- Calculate the arc distance along the geoconcentric surface at radiosonde height
- Calculate the x and y components of the arc distance
- Calculate the winds - u and v vector components; wind speed and direction
- Calculate the latitude and longitude of the radiosonde

10.2.2 Convert Geopotential Height to Geometric Height

The WsART will convert the geopotential height of each data point to geometric height using the following procedure.

1) Use the following equation to convert geopotential height to geometric height (WMO, 1973).

$$z = \frac{R'Z}{\left(\frac{g_\phi R'}{9.80665}\right) - Z}$$

where:

z = geometric height in m

Z = geopotential height in standard geopotential meters

R' = virtual radius of earth at latitude ϕ

and:

$$R' = \frac{2g_\phi}{-\left(\frac{\delta g}{\delta z}\right)_{z\,=\,0}}$$

where:

g_ϕ = acceleration of gravity at sea-level and latitude f;

g_ϕ = 9.80616[1.0` - Acos(2ϕ) + Bcos^2 (2ϕ)]

A = 2.6373 x 10^{-3} B = 5.9 x 10^{-6}

and:

$$\left(\frac{\delta g}{\delta z}\right)_{z=0} = A + B\cos(2\phi) - C\cos(4(2)\phi)$$

A = 3.085 426 x 10^{-6} B = 2.27 x 10^{-9} C = 2.0 x 10^{-12}

and:

ϕ = latitude

Note that the standard geopotential meter was adapted by the WMO (WMO TR, Volume I, edition 1971, Appendix C, section 7) as the unit of geopotential and from 1 July 1972 replaced the geopotential meter. One standard geopotential meter is 9.80665 J Kg^{-1} whereas one geopotential meter is 9.80 J Kg^{-1}. This change is reflected in the equations used above.

The NWS adapted this convention for their rawinsonde observations starting 1 October 1993, with the operational release of MicroART software Version 1.52.

10.2.3 Calculate the Earth's Radius at Station Latitude

The radius of the earth at the station latitude, using World Geodetic Survey, 1984, (WGS 84) values for the earth's equatorial and polar radii, can be found using the following equations for an ellipsoid.

$$R_{\phi} = R_{equ}[1 - f\sin(\phi)^2]$$

where:

R_f = earth's radius at latitude f

R_{equ} = Equatorial radius, WGS84 = 6 378 137.000 meters

R_{pol} = Polar radius, WGS84 = 6 356 752.314 meters

and:

flattening:

$$f = \frac{R_{equ} - R_{pol}}{R_{equ}}$$

10.2.4 Calculate the Central Earth Angle between Station and Radiosonde

Combining of equations from Clem (1954) and Williams (1993), and adding an adjustment for station height, the following equations are used in Section 10.2.4 through Section 10.2.7 . Use the following equation to find the central earth angle between the station's and radiosonde's position vectors.

$$\Theta = \operatorname{acos}\left(\frac{\cos(\lambda)(R_{\phi} + z_{stn})}{R_{\phi} + z_{rs}}\right) - \lambda$$

where:

λ = Art elevation angle (i.e., angle for Art's level to radiosonde)

R_f = earth's radius at latitude f

z_{stn} = geometric height of station above sea-level

z_{rs} = geometric height of the radiosonde above sea-level

10.2.5 Calculate Arc Distance along the Geoconcentric Surface at Sonde Height

The distance from the station's zenith to the radiosonde's position along the arc at the radiosonde's geometric height can be found using the following equation

$$D' = \Theta(R_{\phi} + Z_{rs})$$

where:

D' = arc distance subtended by q along the geoconcentric surface at radiosonde height

10.2.6 Calculate x and y components of the Arc Distance

The zonal (X) and meridional (Y) components of the arc distance can be found using the following equations. Note that the ART reports a back-azimuth, so its reciprocal represents the true azimuth to the radiosonde.

$$x = D' \sin(az)$$

$$y = D' \cos(az)$$

where:

x = radiosonde's east distance from station

y = radiosonde's north distance from station

az = true azimuth angle from north to radiosonde

10.2.7 Calculate the Winds

The vector components of the wind can be found by differentiating the radiosonde's X and Y positions with respect to time. The west-to-east vector component of the wind is designated as u; the south-to-north vector component as v.

$$u = \frac{\Delta x}{\Delta t}$$

$$v = \frac{\Delta y}{\Delta t}$$

where:

Δx = east-west radiosonde displacement during Δt

Δy = north-south radiosonde displacement during Δt

Δt = time duration between corresponding radiosonde position displacements

10.2.7.1 Wind Speed and Direction

The WsART will report the wind velocity (direction and speed). The wind speed is the magnitude of the combined u and v vector components.

1) Use the following equation to determine the wind speed (in knots) at any data point

$$Wind_{speed} = 1.943(u^2 + v^2)^{\frac{1}{2}}$$

where:

u = west-to-east wind vector component in m/s

v = south-to-north wind vector component in m/s

2) use the following equation to determine the wind direction (geographical direction from which the wind is blowing) at any data point in degrees

$$Wind_{Direction} = 270 - \frac{180}{\pi}\operatorname{atan}\left(\frac{v}{u}\right)$$

This requires an “ATAN2" type arc tangent function that returns the correct value (*radians*) depending on which mathematical quadrant the wind vector lies in. Add 360 to the wind direction if it is negative.

10.2.7.2 Calculate Wind Shear

The magnitude of the wind shear between any level and another level is given by

$$Wind_{shear} = \frac{[(u_i - u_{i-1})^2 + (v_i - v_{i-1})^2]^{\frac{1}{2}}}{\Delta z}$$

10.2.8 Calculate Radiosonde Latitude/Longitude

Knowing the station latitude/longitude, the azimuth and the sea-level arc distance to the radiosonde (i.e., use 0 m for z_{rs} in equation 4), the latitude/longitude of the radiosonde can be calculated using the direct solution method described in Vincenty (1975).

1) Use the azimuth and arc distance to the radiosonde together with equation 8 to solve for f_2, the radiosonde latitude.

2) Solve equation 11 for _*L*. Add _*L* to the station longitude to get the radiosonde longitude.

The following is excerpted from Vincenty:

Notation:

a,*b* = major and minor semi-axes of the ellipsoid

f = flattening = (*a*-*b*)/*a*

f = geodesic latitude, positive north of the equator

ΔL = difference in longitude, positive east

s = length of the geodesic

α_1, α_2 = azimuths of the geodesic, clockwise from north, α2 in the direction P1P2 produced

α = azimuth of the geodesic at the equator

$$u^2 = \frac{a^2 - b^2}{b^2}\cos(\alpha)^2$$

U, reduced latitude, defined by: tan U = (1- f) tan f

λ = difference in longitude on an auxiliary sphere

s = angular distance P1 P2 on the sphere

s_1 = angular distance on the sphere from the equator to P1

s_2 = angular distance on the sphere from the equator to the midpoint of the line

Direct Formulae:

Equation 1,

$$\tan(\sigma_1) = \frac{\tan(U_1)}{\cos(\alpha_1)}$$

Equation 2,

$$\sin(\alpha) = \frac{\cos(U_1)}{\sin(\alpha_1)}$$

Equation 3,

$$A = 1 + \frac{u^2}{256}[64 + u^2(5u^2 - 12)]$$

Equation 4,

$$B = \frac{u^2}{512}[128 + u^2(37u^2 - 64)]$$

Equation 5,

$$2\sigma_m = 2\sigma_i + \sigma$$

Equation 6,

$$\Delta\sigma = B\sin(\sigma)\left[\cos(2\sigma_m) + \frac{B}{4}\cos(\sigma)(2\cos(2\sigma_m)^2 - 1)\right]$$

Equation 7,

$$\sigma = \frac{s}{bA} + \Delta\sigma$$

Eq. 5, 6, and 7 are iterated until there is a negligible change in s. The first approximation of s is the first term of 7.

Equation 8,

$$\tan(\phi_2) = \frac{\sin(U_1)\cos(\sigma) + \cos(U_1)\sin(\sigma)\cos(\sigma_1)}{(1 - f)[\sin(\alpha)^2 + (\sin(U_1)\sin(\sigma) - \cos(U_1)\cos(\sigma)\cos(\alpha_1))^2]^{\frac{1}{2}}}$$

Equation 9,

$$\tan(\lambda) = \frac{\sin(\sigma)\sin(\alpha_1)}{\cos(U_1)\cos(\sigma) - \sin(U_1)\sin(\sigma)\cos(\alpha_1)}$$

Equation 10,

$$C = \frac{f}{16}\cos(\alpha)^2[4 + f(4 - 3\cos(\alpha)^2)]$$

Equation 11,

$$\Delta L = \lambda - (1 - C)f\sin(\alpha)(\sigma + C\sin(\sigma)[\cos(2\sigma_m) + C\cos(\sigma)(2\cos(2\sigma_m)^2 - 1)])$$

Equation 12,

$$\tan(\alpha_2) = \frac{\sin(\alpha)}{\cos(U_1)\cos(\sigma)\cos(\alpha_1) - \sin(U_1)\sin(\sigma)}$$

End of excerpt.

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11. Administrative Reports

All upper-air sites are required to generate and transmit a series of upper air forms and reports. These forms are generated as part of the normal operation of all upper-air sites. The forms contain information such as balloon and radiosonde inventory at the site, defective equipment, normal observations performed during the reporting period, and special observations performed during the reporting period.

These reports are currently generated manually at the upper-air site with the exception of the missing data report which is a new report.

A requirement of WsART will be to automate the generation and transmittal of these form and reports at the appropriate time to the appropriate parties. WsART will be required to generate and transmit (possibly electronically) the following upper-air forms and reports:

- B-29, Rawinsonde Report
- B-85, Rawinsonde Inventory
- B-47, Rawinsonde Monthly Transmittal
- H-6, Report of Defective Radiosondes
- A-22, Special Upper-Air Observation Report
- Missing Data Report

These forms will all be generated from information stored in the local database. WsART will automatically calculated and update fields related to inventory thus providing inventory control for the upper-air site.

11.1 B-29, Rawinsonde Report

This report contains information such as detailed descriptions of each successful observation during the reporting period, descriptions of each unsuccessful release, lists of rejected equipment or missing equipment for the reporting period. WsART will generated this form three times each month and the form will contain the following information:

General Information:

Station Name:	-	The station name from the station data file.
Prepared by/verified by:	-	This field is left blank. The operator will be prompted for this value when the administrative forms are generated.
Report date:	-	The date the form is generated.

Flight Equipment Information:

List of rejected instruments	-	WsART will supply this information from the local data base. This information will include the serial number, date, time, observer and reasons for all rejected instruments.
List of rejected batteries	-	WsART will supply this information

		from the local data base. The information includes the type, shipment no, and date of mfg. Also included are date and time of rejection, Observer name, and reason for rejection.
List of defective balloons	-	WsART will supply this information from the local data base. The values in this field include balloon type and Mfg. lot no. Also included are date and time of rejection, Observer name, and reason for rejection.
List of the missing hygristors	-	WsART will extract this information from the inventory file in the local data base. The information contained in this field include the number of missing hygristors, and the shipment number.
List of the missing batteries	-	WsART will extract this information from the inventory file in the local data base. The information contained in this field include the number of missing batteries, and the shipment number.

Unsuccessful Releases Information:

Flight date	-------	
Scheduled release time	|	
Radiosonde serial number	|	
Balloon mfg and lot number	|	- WsART will extract this information from
Nozzle lift/Cubic Feet	|	the flight tables.
Battery mfg and lot number	|	
Termination reason	|	
Observer Initials	-------	
Remarks	-	Operator entered at prompt
General Remarks	-	Operator entered at prompt

Observational Summary Information:

Ascension Number	-------	
Date (UTC)		
Operator initials	|	
Scheduled Release Time (UTC)	|	
Radiosonde Serial Number	|	
Balloon mfg and lot number	|	
Nozzle Lift/Cubic Feet	|	- WsART will extract this information from
Ascent rate (sfc to 400 hPa)	|	the flight tables.
Ascent rate (400 hPa to term)	|	
Termination Reason	|	
Termination Height (meters)	|	
Wind termination reason	|	
Elapsed Flight Time	|	
Highest Pressure Reached	-------	

Remarks	-	Operator entered at prompt

11.2 B-85, Rawinsonde Inventory

WsART will be required to generate the Rawinsonde Inventory report (form B-85) once each month. This report contains information relating to radiosonde inventory for the specific month and contains the following entries:

Station Name	-	Retrieved from the Station Data file in the local local data base.
Report date	-	Report generation data from the workstation clock.
Prepared by/verified by:	-	Intentionally left blank. This field will be filled
Title	-	Blank.
Monthly Inventory		

The following information is reported for radiosondes types (artsonde, recon, loran, and GPS), balloons, parachutes, train regulators, lighting units, batteries:

Beginning balance	-	Retrieved from the Inventory data base.
Number received during the month	-	Retrieved from the Inventory data base.
Total available during the month	-	Computed by the WsART software.
Number release during the month	-	Computed by the WsART software. These values will be retrieved from the flight log/summary.
Number of shipped units	-	Field must be filled in by the observer.
Number of rejected units	-	Computed by the WsART software. Values are available in the Flight log/summary.
Total number used	-	Computed by the WsART software.
Ending balance	-	Computed by WsART software.
Ending Balance	-	Copied from above.
Num of defective sondes on hand	-	Left blank to be filled by observer.
Num of defective sondes shipped	-	Left blank to be filled by observer.
Shipment number	-	Shipment Number for radiosondes received
Date shipment received		

The following supplemental information is also reported:

Hydrogen/helium cylinders(Starting Balance, Number received, action taken, ending balance)

General Remarks	-	Left blank to be filled by observer
Hygristors		
Balls of twine		

11.3 B-47, Rawinsonde Monthly Transmittal

WsART will be required to generated the Rawinsonde Monthly Transmittal (Form B-47) once each month. This report contains information pertaining to special and missing observations, and minor observation changes.

The report will contain the following information:

Station Name:	-	Retrieved from the Station data file (table).
Period of records (month/year)	-	The current month and year of the report as supplied by the workstation.
Date Submitted	-	The data the form is generated as supplied by the workstation.
Number of Successful flights	-	Value provided by the software. This data is available through the flight summary.
List of special observations by project	-	Date, time, project name, NWS funded (Y/N), # hours OT, and reason for special obs. This information will be supplied by the WsART software.
List of special observations by request	-	Date, time, requesting individual or agency, and reason for special obs. This information will be supplied by the WsART software.
List of missing observations	-	Date, time, and reason for missing the obs. This information will be left blank to be filled in by the observer.
Remarks	-	Left blank to be filled by observer.

11.4 H-6, Report of Defective Rawinsondes

This form is not generated at any specific interval but rather is generated each time defective radiosondes are shipped. WsART will not generate this form.

The report contains the following information:

Station Name	-	Retrieved from the station data file
Shipping Date	-	The data the form is generated as supplied by the workstation software.
Shipped to	-	The default value for this field will be the address of NRC. Optionally the operator can select another destination such as the radiosonde vendor.
Method of Shipment	-	GBL, FedEX, USPS

For each defective radiosonde shipped, the following information is supplied on the report:

Serial Number	-	This value is provided by the software. The data is available through the flight summary or inventory data base.
Date of Acceptance	-	This field may be left blank. This value for this field comes from the radiosonde.
Date Rejected	-	Provided by the software. This data will be available in the flight summary or inventory data base.

Reason For Rejection	-	Provided by the software. This data is available in the flight summary or inventory data base.
Official in Charge	-	Left Blank to be filled by the observer or official.

11.5 A-22, Special Upper-Air Report

The Special Upper-Air Observation Report (form A-22) will be generated by WsART once a month on the last day of the month. Sites may have multiple projects. In which case, a report will be generated for each project. The special upper-air report will not be generated if the project is NWS Funded.

This report is project specific and contains the following information:

Station Name	-	This value will be extract from the station datafile.
Date of the Report	-	The data the form is generated as supplied by the workstation.
Total Number of Observations	-	Provided by the software. This data is available in the flight summary.
Project Name	-	Provided automatically by the software.
Project Number	-	Provided automatically by the software.

For each special observation the following information is provided (date, time, # hours Overtime, Reason for special observation)

Prepared by	-	Left blank to be filled by Observer.

11.6 Missing Data Report - New Report

The missing data report is generated once at the end of each month. The report categorizes the flights during the month based on the amount of missing PTU and wind data observed during a sounding. This report contains separate sections for PTU and wind missing data.

The flights are categorized based on the amount of missing data observed for a specific layer or stratum. The report will arrange flights into the following categories/groups. WsART will log the necessary data to maintain and create this report at the end of each flight.

Station Name:	-	Software provided from the database.
Date:	-	The date the report was created.
Prepared by:	-	Left Blank to be filled by the observer.

For each ascension number and release number, the following information will be provided.

	PTU and winds DATA:		Missing and/or rejected data.	
	Data Loss Allowed for the Entire Flight			
Flight time 0-120 min	Pressure	Temperature	RH	Winds
	Data Loss for Specified Time Periods of the Flight			
Flight time	Pressure	Temperature	RH	Winds

0 to 5 min
5 to 15 min
15 to 30 min
30 to 60 min
60 to 120 min

11.7 Specific Requirements for Administrative Reports

- WsART will be required to generate the B-29 (Rawinsonde Report) three times a month.
- WsART will notify the operator when the B-29 form has not been generated “on-time”. The B-29 form should be generated at the following times:
    - 00Z on the 11th day of the month.
    - 00Z on the 21st day of the month.
    - 12Z on the 31st (last day) of the month.
- WsART will have an inventory data base to hold the inventory information needed on these forms.
- WsART will be required to have a utility providing for input of inventory data which is not part of the station data or pre-release.
- The date of last calibration, elevation difference, azimuth difference, and date of last theodolite check will be added to the station data file to facilitate automated report generation.
- WsART will include a new screen displayed when an unsuccessful release occurs. This screen will prompt the operator for the remarks field for the unsuccessful release.
- A configuration option will be added to WsART to toggle between “nozzle lift” and “cubic feet” as section headings.
- WsART will include a new screen displayed when an successful flight occurs. This screen will prompt the operator for the remarks field for the successful flight.
- A new inventory data base will be created. This data base will contain inventory information for such things as radiosondes, batteries, balloons, etc.
- A Software utility must be created to allow the operator to fill in any/all empty fields in the reports prior to transmission.
- A additional window(screen) will be added to the prerelease when a special observation is taken. this screen will prompt the operator for the project name and number.

12. RRS Subsequent Builds

Many features of the final RRS will not be included in the initial release of the RRS (WsART) but rather will be included in the subsequent builds. This section details the changes/enhancements that are planned for the subsequent builds of the RRS. These enhancements will not require a complete redesign but rather, will be made to the software developed for WsART. The following enhancements/additions are slated for the RRS in the subsequent builds:

- Integration of automated surface observation equipment.
- Integration with AWIPS.
- GPS position data from the SPS.
- Client/Server Requirements

The following sub-sections detail the requirements for all enhancements/changes to be made in the subsequent builds of the RRS. The requirements are grouped by enhancement. In other words, all requirements for integrating automated surface observation whether they are specific to the User Interface, configuration or other section of the software are contained in the surface observation section.

12.1 Automated Surface Observation Equipment

For the subsequent builds of the RRS, WsART will be modified to interface a series of automated surface observation equipment with the workstation. The automated surface observation equipment interfaced will include precision sensors to automatically measure the following meteorological parameters:

- Pressure
- Temperature
- Relative humidity.
- Wind speed
- Wind direction

Even in the subsequent builds of the RRS certain surface observation values cannot be automatically measured. The current weather conditions including cloud cover, and cloud types and present weather are an example of surface parameters not automatically measurable.

When automated instruments are installed and interfaced to the workstation, the RRS must allow the operator to enter some or all of the surface observation data manually to permit recovery from a malfunction in the automated instruments.

12.1.1 Specific Workstation Requirements for Surface Observation Equipment

- The PC software (RRS) shall perform the control and data acquisition functions necessary to obtain surface data from the precision instruments interfaced to the workstation when those instruments are present and operational.
- The PC software (RRS) shall automatically acquire surface observation measurements for zero or more of the following physical quantities:
  Pressure.
  Dry Bulb Temperature.

Relative Humidity or Dewpoint or Wet Bulb.
Wind Speed (in knots).
Wind Direction (in degrees).

- The maximum required workstation sample rate for surface measurements is two samples per second; the minimum rate shall be the maximum sample rate of each instrument.
- The RRS shall continuously monitor automated surface readings and shall record those readings on a permanent storage device.
- The RRS shall allow the operator to accept one or more of the automated surface measurements as the official surface observation.
- The RRS shall always allow the observer to enter surface observation data to be used in place of automated measurements.
- Pressure values, entered for the surface observation, shall be corrected for height differential between the measuring instrument and the radiosonde release point.
- When automated surface observation instruments are available the RRS shall record the readings as close as possible to the time of balloon release. These values shall be displayed for the operator and a control shall be provided whereby the operator can accept one or more of the automated readings at release as the official observation.
- The surface observation values obtained from automated instruments at release shall be retained with the detailed flight record regardless of whether or not the operator chooses to use any of them for the official observation.
- The RRS shall allow the operator to manually change the value of any surface observation datum before, during, or after a sounding.
- The RRS shall require the operator to confirm measurements from automated instruments before they are used for the official surface observation.
- The RRS shall be required to perform hardware checks for the precision automated surface observation equipment and the interfaces to the equipment.
- The RRS shall be capable of displaying and updating the reference pressure field value in the baseline status window based on the pressure reading from the automated surface observation equipment. This value must be updated at a rate of at least two times per second, until the reading is locked by the operator. (Locking the reading means freezing the display at the current value to prevent further updating.) The operator should also enter a value manually, even when there is an automatic pressure measuring device.
- The RRS will be required to display three sets of surface observation data in the surface observation window in addition to the information already displayed in the surface observation display. This information includes:
  The current reading from each surface observation instrument updated automatically.
  The readings from the surface observation instruments at the time of release.
  The values for the actual surface observation.
- The actual surface observation are the data that will be reported as the surface data for the observation. This window shall have controls to set the values for the official surface observation from either the current readings or the readings at the time of release. This window shall also have controls to selectively inhibit display of data from any of the surface observation instruments.
- All transaction between the RRS and the surface observation equipment shall be

stored in the log record.

12.2 AWIPS Requirements for the RRS

One goal of the RRS development effort is to have the RRS integrated into AWIPS as much as possible. The integration will be accomplished by connecting the RRS PC (those collocated with AWIPS) directly to the AWIPS LAN. The integration of the RRS with AWIPS will allow the RRS to:

- Support remote execution of the RRS functionality on an AWIPS workstation
- Provide the upper-air DDS/PDS data set to AWIPS processes.
- Access peripherals connected to the AWIPS LAN.
- Transmit the final upper-air observation product to AWIPS via the LAN connection.

Even though the RRS will be completely integrated into AWIPS, the RRS will be completely dedicated for upper-air support during the radiosonde sounding. During a sounding, access to the RRS, its data, and peripherals by AWIPS clients will be severely limited.

12.2.1 Remote Execution of RRS Functionality

The RRS will be required to act as an application server. This will allow registered AWIPS workstations to execute a set of specific processes offered by the RRS. All processing and data will remain on the RRS (server), and the data will be displayed on the AWIPS workstation (client).

AWIPS software which is out of the scope of the RRS development effort will be required to log on the AWIPS workstation to allow users to execute the RRS processes or applications.

12.2.2 Availability of DDS, PDS, and WMO Message Data to AWIPS Processes

The RRS will be responsible for managing the acquisition and storage of the upper-air data sets. The acquired data will be stored in the RRS local database and will be made available to registered AWIPS workstations via standard Application Programming Interface (API) calls.

AWIPS will be required to develop the software needed to access the data stored in the RRS database.

12.2.3 RRS Access to AWIPS Peripherals

The RRS will be capable of accessing any peripheral connected to the AWIPS LAN. The exact specification for accessing UNIX resources from a WindowsNT client has not been determined as yet.

12.2.4 Delivery of the Final Observation Product via the AWIPS LAN

In addition to the dial ports defined in the AWIPS SSS, RRS workstations connected to the AWIPS LAN will be required to offer the option of delivering the upper-air observation data products (WMO coded messages, PDS, and DDS) via the LAN connection. The method of transmission used for the final product will be a site configuration item in the RRS.

12.2.5 Specific Requirements for AWIPS Integration

- The RRS PC will be connected to the AWIPS LAN.
- The RRS will be able to access any peripheral connected to the AWIPS LAN.
- The RRS will be available as an AWIPS resource when sounding activities are concluded.
- The RRS will be required to supply the DDS to the protected AWIPS network via the LAN when not performing a sounding.
- The RRS will allow any workstation connected to the AWIPS LAN to remotely execute RRS applications.
- The RRS will be totally dedicated to upper-air observations. AWIPS execution of RRS software will be disabled during a sounding.
- A configuration option will be added to the site configuration file for determining the method of transmission for the DDS. The value will either be “Modem” or “LAN”.
- The current RRS design isolates the workstation to the AWIPS network. Any future communications requirements that necessitate a link outside the protected AWIPS network shall: be approved by the AWIPS program office; go through a “firewall”.

12.2.6 Integration of GPS Radiosondes and Tracking

During the subsequent builds, the RRS system will be enhanced to track the radiosonde using the network of Global Positioning Satellites. This enhancement will involve replacing the RDF tracking system used in WsART with a GPS tracking system.

The SPS will supply the workstation software with the GPS tracking data. This data will include the radiosonde position, a measurement of the winds aloft, and the altitude of the radiosonde.

The WsART workstation software must be modified to reflect the change in tracking systems. The software will no longer be required to calculate the winds aloft, as these values (U,V) will be supplied by the SPS.

12.2.7 Specific Requirements for GPS Integration

- All GPS tracking data for the RRS will be supplied by the SPS.
- The SPS will supply the RRS with GPS tracking data such as the wind U and V vectors, and the altitude of the radiosonde. Where possible, the SPS should also provide the latitude and longitude of the radiosonde if these values are supplied by the radiosonde.
- The SPS shall determine upper air winds based on the movement of the radiosonde during ascent.
- The position data record contents must be modified to reflect the position data supplied by the GPS radiosondes.
- The time-tag associated with each PTU data point and placed in the meteorological data file will be the time reported by the GPS radiosonde.

12.3 Client/Server Requirements for Subsequent Builds

The RRS workstation, its data files, and the RRS software modules will be required to be available for remote usage/execution in the subsequent builds. The RRS will allow for this remote access/execution through a client/server interface. Through this interface, the RRS will function as the server (provider) and the remote host will act as the client (user).

In the RRS, the client/server requirements refer to the specific ability of the RRS to allow:

- Remote execution of all RRS software applications.
- Remote usage of all RRS generated data.
- Remote administration of the RRS software, the WindowsNT operating system, and the INFORMIX database.

12.3.1 Remote Execution of RRS Application and its Associated Processes

All remote execution of RRS software will be accomplished by remotely executing processes on the client connecting to the RRS server. Remote access to the RRS software through the client/server interface will be configurable through the site configuration file and will be controlled by the RRS software.

12.3.2 Data Availability

The RRS will allow for remote access through the client/server interface to the data stored in the RRS local database. All access to the data in the database will be through a standard API using an INFORMIX database SQL call. The number of remote connections to the database and the users/hosts permitted to connect to the database shall be a configurable option.

12.3.3 Remote Administration

The RRS will allow for remote administration of the RRS, the WindowsNT operating system, and the local RRS INFORMIX database. The remote administration may occur through remotely executing processes which provide the administration and may include tasks such as tuning the operation of the local database, configuring the RRS software through changes to the site or system configuration file, and/or accessing or loading changes for remote connections to the RRS.

12.3.4 Specific RRS Client/Server Requirements

- The RRS shall be able to block remote access to the RRS, its software, and its data. The selective blocking of hosts or users shall be a configuration option most likely in the site configuration file.
- The RRS software shall be able to limit the number of RRS processes running both locally and remotely. This will be a configuration option in the site configuration file.

12.4 Additional Requirements for Subsequent Builds

There are several requirements for the subsequent builds of the RRS which are not specific to one of the above listed enhancements. These requirements are listed in this section.

- In the subsequent builds of the RRS, radiosondes may be utilized which transmit the calibration data as part of the data stream. The RRS will read the calibration data from PTU SPS and save it with detailed flight data. Additionally, the RRS will provide the capability of sending the calibration parameters to the SPS when the SPS requests the transmission of the calibration data.
- The balloon release detection for the subsequent builds of the RRS will be enhanced. The RRS will be required to detect balloon release in one of two ways. Either through a message sent to the workstation from the SPS unit or automatically via analysis of the pressure data stream . A configuration option will be added to determine the

method of release detection.

- The RRS will be required to provide operator control for the antenna and receiver sub-systems. This control will be through the SPS and two additional windows will be added to the user interface to facilitate the control. One window to control the receiver, and one to control the antenna. The specific contents of these windows has not been completely defined.
- The RRS software will be backwards compatible. The RRS will be required to read and process data archives created by WsART, and all previous versions of the RRS.
- The RRS will be required to transmit the DDS to NCEP.

13. Glossary of Terms

Additional Levels - Refers to any levels selected between the Standard and Mandatory Significant Levels. These levels represent a significant departure from a piece-wise linear approximation of the vertical temperature or RH profile.

AWIPS - is an acronym for **A**dvanced **W**eather **I**nteractive **P**rocessing **S**ystem. AWIPS is the key integrating component of the NWS modernization. AWIPS comprises communications, processing, data management, monitoring and control, and display and interaction capabilities required to acquire, process, display and disseminate hydrometeorological information for the NWS.

BILS - is an acronym for Balloon Inflation and Launch Shelter. The BILS is a semi-automatic facility to manually prepare the balloon radiosonde, and associated flight train for a remote controlled balloon launch.

BUFR - is an acronym for **B**inary **U**niversal **F**orm for the **R**epresentation of meteorological data. It is a binary code designed to represent, employing a continuous binary stream, any meteorological data. The BUFR format will be used for all data transfers to both NCDC and NCEP.

Cloud Bases - Refers to the lowest level in the atmosphere that contains cloud particles (water droplets, ice crystals, etc.)

Cloud Tops -

CLS -

Conv. Condensation Lev - The level in the atmosphere to which an air parcel, if heated from below, will rise dry adiabatically, without becoming colder than its environment just before the parcel becomes saturated.

Corrected Data - Refers to the data derived from the raw data by the application of a correction approved by the NWS. Currently, the only data for which a correction is known to be applicable is the temperature which may be corrected for the effects of solar radiation.

Cross Totals Index - The Cross-Totals Index is a stability index and severe weather forecast tool whose value is computed as the Dewpoint at the 850 hPa level minus the temperature at the 500 hPa level. This value is then used in computing the T Totals Index.

Distributed Data Set (DDS)- One of the two products generated by the RRS. This data set will be transmitted to both NCDC and NCEP, and will contain both the raw data reported by the radiosonde the corrected data, and the processed data.

EMRS - is an acronym referring to Engineering Management Reporting System.

Equilibrium Level - The level above the level of free convection at which the temperature of a rising air parcel again equals the temperature of the environment.

Fallout Winds -

Forecast Maximum Temp -

Forecast Minimum Temp -

GDL - is an acronym for **G**reatest **D**eparture of **L**inearity. Used to locate additional levels in a radiosonde report.

Geodynamic -

Geopotential - A measure of potential energy, given by the integral with height (altitude) of the local acceleration of gravity. (Refer) to FMH #3 Appendix D for a more complete description).

GPS - is an acronym for **G**lobal **P**ositioning **S**ystem. The GPS system uses a network of satellites to determine position.

Hail Size -

Helicity - A property of a moving fluid which represents the potential for helical flow (i.e. flow which follows the pattern of a corkscrew) to evolve. Helicity is proportional to the strength of the flow, the amount of vertical wind shear, and the amount of turning in the flow (vorticity). Atmospheric helicity is computed from the vertical wind profile in the lower part of the atmosphere (usually sfc to 3 km), and is measured relative to storm motion. Higher values of helicity (generally, around 150 m^2/s^2 or more) favor the development of mid-level rotation (i.e. mesocyclones). Extreme values can exceed 600 m^2/s^2.

Icing Conditions -

K Index -

KO Index -

LAN - is an acronym for **L**ocal **A**rea **N**etwork.

Level of Free Convection -

Lifted Index - A common measure of atmospheric instability. Its values is obtained by computing the temperature that air near the ground would have if it were lifted to some higher level (around 18 kft, usually) and comparing the temperature to the actual temperature at that level. Negative values indicate instability - the more negative, the more unstable the air is, and the stronger the updrafts are likely to be with developing thunderstorms.

Lifting Condensation Level- The Lifted Condensation Level (LCL) is the level to whichaunsaturatedairwouldhavetoberaisedinadryadiabatic expansion to produce condensation.

Mandatory Sig Levels - A set of WMO-defined pressure values for which the values of temperature, humidity, and wind are reported.

Maximum Gust -

Maximum Parcel Level -

MCU - is an acronym for **M**aster **C**ontrol **U**nit. This refers to the Master Control Unit in the Automatic RadioTheodolite Receiver (ART-2) tracking system. The MCU will supply the angular data to the WsART system and the PTU data to the Signal Processing System (SPS).

MET Decoder - The MET Decoder is synonomous with the SPS system for WsART. They both provide Pressure, Temperature and Humidity data. It is important to note that the SPS will also deliver GPS winds data in the subsequent releases of the RRS system.

Micro-ART - is an acronym for **M**icrocomputer-based **A**utomatic **R**adio **T**heodolite. Micro-ART is the current sounding system in use at upper-air sites.

Mixing Depth -

NCAR - is an acronym for **N**ational **C**enter for **A**tmospheric **R**esearch.

NCDC - is an acronym for **N**ational **C**limatic **D**ata **C**enter.

NCEP - is an acronym for the **N**ational **C**enters for **E**nvironmental **P**rediction.

NEXUS - is an acronym for the **NEX**t **U**pper-air **S**ounding system. NEXUS was designed by NCAR and is an experimental prototype sounding system.

NLSC -

NOAA - is an acronym for **N**ational **O**ceanic and **A**tmospheric **A**dministration.

NRC -

NWS	-	is an acronym for National Weather Service.
PIBAL	-	Meteorological jargon for a Pilot-balloon. Also used to denote the determination of upper winds by the tracking of a free balloon.
Precipitable Water	-	
Pre-release	-	Refers to a series of events or the time from when a new observation was selected until the balloon is released (flight).
Processed Data Set (PDS)	-	One of the two data products generated by the RRS. The Local Processed Data set will be the source of data used to generate the WMO coded messages, drive various indices used for operations, and for other applications requiring processed data. This data will be derived by processing the high resolution data reported by the radiosonde during its ascent.
Processed Data	-	Refers to the data derived from the raw or corrected data by applying Q/C techniques, observer “corrections”, and smoothing algorithms. The Processed data will be the source of data used to select levels, generate the WMO coded messages, and derive various indices used for operations.
PTU	-	is an acronym for **P**ressure, **T**emperature and h**U**midity. This acronym relates to the basic meteorological values acquired during an observation.
RADAT	-	is an acronym for **RA**diosonde observation **DAT**a. The RADAT message transmitted as part of an observation contains information relating to freezing levels (zero crossings).
RAOB	-	is an acronym for **Ra**diosonde **Ob**servation.
Raw Data	-	Refers to the value of the physical parameters measured over one radiosonde sample period. The raw data is pressure in hPa, temperature in degrees Celsius, and relative humidity in percent. Each raw data value is derived from directly from the radiosonde measurement for a single, non-overlapping sample interval. Raw data values may be arrived at by some form of averaging, provided that the averaging time is less than or equal to the reporting period,andeachreportedvaluederivesfromindependentdata. Raw values are not smoothed or interpolated.
RDF	-	is an acronym for **R**adio **D**irection-**F**inder. An Instrument for determining the direction from which radio waves approach a receiver. A device which can “home” or “lock

onto" a transmitted radios' signal and determine the location of the source.

RRS - is an acronym for **R**adiosonde **R**eplacement **S**ystem. The RRS will be the next generation sounding system and will replace the Micro-ART system now in use at upper-air sites.

Showalter Index - The showalter index is a stability index. It is calculated by taking the 850 hPa temperature and dewpoint to compute the LCL at which the parcel is raised up its super adiabat to compute the 500 hPa temperature. The difference between the actual temperature at the 500 hPa level and the computed temperature is the showalter index.

Skew-T - A graphical representation of pressure, temperature, and humidity made in an vertical sounding based upon thermodynamic laws. The coordinates are temperature and the logarithm of pressure, with the temperature isotherms rotated 45 degrees. The graphical representation is such that an area on the diagram is proportional to energy.

SPS - is an acronym for the **S**ignal **P**rocessing **S**ystem. The SPS decodes radiosonde telemetry signals and provides thermodynamic and wind data to the RRS workstation for analysis.

SQL - is an acronym for **S**tructured **Q**uery **L**anguage. SQL is a programming language used to query and store information in relational databases.

Standard Levels - a set of WMO specified pressure levels at which the pressure, temperature, height, time, and winds are provided. The standard levels include the following pressure levels (hPa) surface, 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, 10, 7, 5, 2, 1.

Telemetry Data - Refers to the radiosonde data transmitted to the ground from the radiosonde. This data is converted to the values reported by the SPS through the application of vendor specific algorithms which typically require coefficients from the calibration data for the radiosonde. Telemetry data will be different for each type of radiosonde and will depend on the measurement and telemetry techniques used.

Total Totals Index - The Total-Totals Index is a stability index and severe weather forecast tool whose value is computed as the sum of the temperature at the 850 hPa level and dewpoint at the 850 hPa level minus twice the temperature at the 500 hPa level. The Totals total index is the sum of the Vertical-

Totals Index and the Cross Totals Index.As with any stability index there are no magic threshold values, but in general, values of less than 50 or greater than 55 are considered weak and strong indicators, respectively, of potential severe storm development.

Turbulence -

UCAR - is an acronym for **U**niversity **C**orporation for **A**tmospheric **R**esearch.

UTC - is an acronym for **U**niversal **T**ime **C**oordinated - after the French equivalent.

Vertical Totals Index - The Vertical-Totals Index is a stability index and severe weather forecast tool whose value is computed as the temperature at the 850 hPa level minus the temperature at the 500 hPa level. This value is then used in computing the T Totals Index.

WBAN - is an acronym for **W**eather **B**ureau **A**rmy **N**avy identification number.

WMO - is an acronym for **W**orld **M**eteorological **O**rganization.

WsART - is an acronym for Workstation-ART. WsART is the first release of the RRS. It implements the Micro-ART sounding system on an WindowsNT based PC while using the new SPS to deliver PTU data, and the new BILS shelter to provide remote balloon release.

14. Data Analysis Tools

An additional set of data analysis tools is desirable for both WsART and the complete RRS system. The extra values are not required to generate the code messages or in level selection but rather provide additional information to the observer during a sounding. It is important to note that the data analysis tools are secondary requirements and may not be delivered in WsART or any of the subsequent builds of the RRS. The following additional values may be computed by the WsART software:

- Lifted Index
- K Index
- KO Index
- V total index
- C total index
- T total index
- Convective Condensation Level
- Level of free convection
- Equilibrium level
- Maximum Parcel Level
- Cloud bases and tops
- Icing Conditions
- Turbulence
- Forecast maximum and minimum temperature
- Hail size
- Maximum Gust
- Helicity
- Precipitable Water
- Mixing Depth
- Fallout Winds

A. Appendix - Upper-Air Reports Templates

This appendix contains graphical representations of each upper-air report maintained and created by the WsART system. The contents of each report are described in Section 11.

A.1   B-29 Rawinsonde Report

WS FORM B-29	U.S. DEPARTMENT OF COMMERCE NOAA National Weather Service	Station	
RAWINSONDE REPORT		Verified By	Date

Flight Equipment

	DATE	TIME	Observer	REASON
INSTRUMENTS REJECTED (*Serial No.*)				
BATTERIES REJECTED (*Type, Shipment No. And Date of Mfg.*)				
DEFECTIVE BALLOONS (*Mfg. Lot No. And Type*)				

NUMBER OF MISSING HYGRISTORS	SHIPMENT NUMBER
NUMBER OF MISSING BATTERIES	SHIPMENT NUMBER

UNSUCCESSFUL RELEASES

Date	Sched. Time of Release	Radiosonde Serial No.	Balloon Mfg. and Lot No.	Nozzle Lift/ Cubic Feet Of Gas	Battery Mfg and Lot No.	Term. Reason	Obs. Initials	Remarks

GENERAL REMARKS

Observational Summary - Successful and Missing Releases - Scheduled and Special

Asc. No.	Date	Scheduled Time of Release	Radiosonde Serial No.	Balloon				Term Reason	Termination Height	Wind Term	Elapsed Flight Time	Highest Pressure Reached	Obs Init.	Remarks
				Mfg and Lot No.	Nozzle Lift or Cobic ft.	Ascent Rate								
						Sfc to 400 hPa	400 hPa to Term							

Code for "TERMINATION REASON"
* Enter details under "REMARKS"

1 - Balloon burst
2 - Balloon forced down by icing
3 - Leaking or Floating balloon
*4 - Weak or fading signal
5 - Battery Failure
*6 - Ground equipment failure
*7 - Switching Failure
*8 - Radiosonde failure
9 - Other
*10 - Exxcessibe missing data

A.2 B-85 Rawinsonde Inventory

WS FORM B-85 **RAWINSONDE INVENTORY**	Station:
TO: ( ) NWS Headqusrters 1325 East-West Highway SSMC - Room 17372 Silver Spring, MD 20910 ( ) NWS Regional Headquarters	Date: Prepared By/Verified By: Title:

Monthly Inventory	Radiosondes					Balloons		Parachutes	Train Reg	Light Un.	Batteries
Item	ART	Recon	VLF	Loran	GPS	Kaysam	Totex				
1. Beginning Balance											
2. Number Received During Month											
3. Total Available (Line 1 + 2)											
4. Number Used During Month											
5. Number Shipped											
6. Number Rejected											
7. Total Used (Lines 4+5+6)											
8. Ending Balance (Line 3 - Line 7)											
9. Ending Balance (Actual Count/Servicable Units)											
10. Defective Units on Hand											
11. Quantity of Defective units shipped											
12. Shipment Number											
13. Date Shipment Received											

Supplimental Inventory Information and Remarks

Cylinder Type	Starting Balance	Number Received	Action Taken	Ending Balance
Hydrogen				
Helium				

	Balls of Twine	Hygristors	Remarks:
Quantity on hand			

A.3 B-47 Rawinsonde Monthly Transmittal

WS Form B-47

U.S. Department of Commerce
National Oceanic and Atmospheric Admin.
National Weather Service

Station

RAWINDSONDE MONTHLY TRANSMITTAL

Period of Records (*Month and year*)

Date Submitted

INSTRUCTIONS - Submit original with montly shipment of rawinsonde records to National Climatic Center, Asheville, N.C. 28801.

Number of Successfull Flights

Special Observation by Project (Includes NWS funded and unfunded obs)

Date	Time	Project Name	NWS Funded (Y/N)	# Hours OT	Reason for Special Observation

Special Observations by Request

Date	Time	Requesting Agency or Office	Requesting Individual	Reason for Request

Missing Observations

Scheduled Date	Scheduled Time	Reason for Missing Scheduled Observation

Remarks

A.4 H-6 Report of Defective Rawinsondes

WS FORM H-6

U.S. DEPARTMENT OF COMMERCE
NOAA
NATIONAL WEATHER SERVICE

REPORT OF DEFECTIVE RADIOSONDES

Prepare THREE Copies. Original and second copy to go with shipment. Retain third copy for station file.
(Additional Instructions in National Weather Service addendum to FMH-3.)

Station	Date Shipped

Shipped To:

Method of Shipment: ☐ Postage and Fees Paid

Serial No.	Date of Acceptance	Date Rejected	Reason for Rejection (*Specific and Detailed*)

Official in Charge

A.5 A-22 Special Upper-Air Report

WS Form A-22 U.S. Department of Commerce National Oceanic and Atmospheric Administration National Weather Service Special Upper-Air Observation Report	Station Date Total Number of Observations
To: 1. W/OSO14 2. Regional Headquarters	Submit seperate reports for each special project where activity occurred during the month. Prepare in triplicate as of the end of each month. Forward the original and first carbon copy to the Regional HQ. The Reqional HQ will retain the copy and forward the original to Weather Service HQ, ATTn: W/OSO14. Retain second copy in station files.
Project Name	Project Number

Summary of Special Observations

Date	Time	# Hours OT	Reason for Special Observation

Prepared By (*Signature*)

A.6 Missing Data Report

Report of Missing Data	Station:
	Date:
	Prepared By/Verified By:

Missing and/or Rejected PTU and Winds Data

		PRESSURE						TEMPERATURE						RH						WINDS					
Ascension No.	Rel No.	MAX	0 - 5 min	5 - 15 min	15 - 30 min	30 - 60 min	60 - 120 min	MAX	0 - 5 min	5 - 15 min	15 - 30 min	30 - 60 min	60 - 120 min	MAX	0 - 5 min	5 - 15 min	15 - 30 min	30 - 60 min	60 - 120 min	MAX	0 - 5 min	5 - 15 min	15 - 30 min	30 - 60 min	60 - 120 min

B. Appendix B - Q/C Flag Definitions

WsART will provide data quality flags with the following variables:

- Corrected pressure
- Corrected temperature
- RH
- Processed winds
- Geopotential height
- Latitude and Longitude of the radiosonde

These variables will be assigned numerical data quality flags that fall into several categories. The categories of Quality Flags are described in Table B-1.

Table B-1: Q/C Flag definitions for WsART

Q/C Flag	Meaning
00	**Data Acceptable**
01 - 19	**Missing Data**
01	Ground system power failure
02	Signal Processing System failure
03	Workstation failure
04	Sensor failure
05	Transmitter failure
06	Excessive radio interference
07	Lost GPS signal
08	Unknown communications failure
09 - 18	Left open for additional reasons
19	Other/unspecified
20 - 39	**Questionable Data**
20	Floating balloon
21	Temperature lapse rate exceeds 9.8 /km
22	Stratospheric RH excess 20%
23	Ascension rate high - 450 to 499 m/min
24	Ascension rate less than 200 m/min

Table B-1: Q/C Flag definitions for WsART

Q/C Flag	Meaning
25	Value suspiciously too low
26	Value suspiciously to high
27	Value suspiciously
28	Wind speed change from previous minute suspicious
29	Wind direction change from previous minute suspicious
30	Excessive change from previous flight
31	Communications error
32 - 38	Left open for additional reasons
39	Other/unspecified
40 - 59	**Recommend Data Rejection**
40	Value below physical limits (e.g., -10% RH)
41	Value above physical limits (e.g., 120% RH)
42	Erratic data
43	Temperature lapse rate exceeds physical limits
44	Ascension rate exceeds 500 m/min
45	Wind speed exceeds physical limits
46	Balloon Overhead
47	Limiting Angles
48	Very weak signals
49	Sensor failure
50	Communications error
51 - 58	Left open for additional reasons
59	Other/unspecified
60 - 120	**Additional Flags**